photon focus

User Manual
OEM-D1312(I)
CMOS Sensor Module

MAN042 10/2010 V2.1

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1

Preface

1.1 About Photonfocus

The Swiss company Photonfocus is one of the leading specialists in the development of CMOS image sensors and corresponding industrial cameras for machine vision, security & surveillance and automotive markets.
Photonfocus is dedicated to making the latest generation of CMOS technology commercially available. Active Pixel Sensor (APS) and global shutter technologies enable high speed and high dynamic range (120 dB) applications, while avoiding disadvantages like image lag, blooming and smear.
Photonfocus has proven that the image quality of modern CMOS sensors is now appropriate for demanding applications. Photonfocus' product range is complemented by custom design solutions in the area of camera electronics and CMOS image sensors.
Photonfocus is ISO 9001 certified. All products are produced with the latest techniques in order to ensure the highest degree of quality.

1.2 Contact

Photonfocus AG, Bahnhofplatz 10, CH-8853 Lachen SZ, Switzerland

Sales	Phone: +41 55 451 07 45	Email: sales@photonfocus.com
Support	Phone: +41 55 451 01 37	Email: support@photonfocus.com

Table 1.1: Photonfocus Contact

1.3 Sales Offices

Photonfocus products are available through an extensive international distribution network and through our key account managers. Details of the distributor nearest you and contacts to our key account managers can be found at www.photonfocus.com.

1.4 Further information

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1.5 Legend

In this documentation the reader's attention is drawn to the following icons:

Important note

Alerts and additional information

Attention, critical warning

Notification, user guide

2

Introduction and Motivation

The OEM camera modules support user specific vision system designs and especially embedded solutions. Other than in Photonfocus cameras and board level cameras the OEM camera modules are not complete vision components. The user has to solve the interfacing to his own electronic solution to get a complete vision solution. From this target some restrictions arise. One restriction is that Photonfocus can not guarantee the correct function of the complete solution. Due to the open architecture of the OEM modules excessive support is often needed to implement the modules in advanced embedded solutions. Under defined boundary conditions Photonfocus provides this service on contract base. The OEM modules are not intended for the use in single volumes. The threshold in volume is from 50 modules and more per year. Long term contracts with the customer ensure the availability of the modules over a long period to predictable production dates.
For low volume projects please refer to our board level or camera products. These products are complete vision products that include the software. Due to the character of the board level and camera products Photonfocus can guarantee for the quality and functionality of these complete vision components.
The use of the OEM camera modules enables the use of the Photonfocus camera firmware and software. Thus the user's own vision system benefit from these concepts. Modifications in the firmware can be made on request on contract base. This applies also to modifications in the Photonfocus software. The user can set up his own software on the base of the PFRemote SDK. The Photonfocus software itself is platform independent and was already ported to different operating systems and embedded solutions.
The control of the camera modules over a low level protocol without the help of a CPU is not supported. The advanced features, like LinLog and FPN correction, require complex control sequences. If user's applications require camera module control over low level commands then only products from the classic Photonfocus product range are to be considered. Please contact the Photonfocus Support for further consultance.
The idea of the OEM modules is to give the user a very easy to use environment for the own development. This is supported with the interface definition on the output of the modules. This interface definition is identically applied to all Photonfocus OEM modules and is based on the well known AIA interface definition for vision systems. The camera modules permit the direct interfacing without any background information of the camera electronic. To reach this goal the modules are sold only with digital interface. This leads to two PCB solutions, which are summarized for an overview in Table 2.1.

Definition	OEM-D1312(I)-40	OEM-D1312(I)-80	OEM-D1312(I)-160
Number of PCBs	2	2	2
Sensor Module	OEM-A1312(I)	OEM-A1312(I)	OEM-A1312(I)
ADC Module	OEM-ADCE-40-LVDS	OEM-ADCE-80-LVDS	OEM-ADCE-160-LVDS

Table 2.1: Overview of the OEM camera modules

3

OEM Specification

3.1 Introduction

The OEM-D1312-160(I) camera modules are built around the monochrome A1312(I) CMOS image sensor from Photonfocus, that provides a resolution of 1312 x 1082 pixels at a wide range of spectral sensitivity. It is aimed at standard and enhanced applications in industrial image processing. The principal advantages are:

- Resolution of 1312 x 1082 pixels.
- Wide spectral sensitivity from 320 to 1030 nm
- Enhanced near infrared (NIR) sensitivity with the A1312I CMOS image sensor.
- High quantum efficiency (> 50%).
- High pixel fill factor (> 60%).
- Superiour signal-to-noise ratio (SNR).
- Low power consumption at high speeds.
- Very high resistance to blooming.
- High dynamic range of up to 120 dB.
- Ideal for high speed applications: Global shutter.
- Greyscale resolution of up to 12 bit.
- On board shading correction.
- 3x3 Convolver for image pre-processing included on board
- Up to 512 regions of interest (MROI).
- 2 look-up tables (12-to-8 bit) on user-defined image regions (Region-LUT).
- Crosshairs overlay on the image.
- Image information and camera settings inside the image (status line).
- Software provided for setting and storage of camera parameters.
- The compact size of only 44 mm x 44 mm and 53 mm x 43 mm makes the OEM camera module the perfect solution for applications in which space is at a premium.
- The OEM camera modules are provided with a standardized low voltage CMOS (LVCMOS) parallel data interface.
- Several temperature monitors are available to supervise system reliability.

The general specification and features of the OEM camera modules are listed in the following sections.

3.2 Feature Overview

Characteristics	OEM-D1312(I) camera modules
Interfaces	Low voltage CMOS (LVCMOS), 3.3 V level
OEM Camera Module Control	PFRemote SDK, PFRemote (Windows GUI) or programming library
Configuration Interface	CLSERIAL (9’600 baud or 57’600 baud, user selectable)
Trigger Modes	Interface Trigger and separate Trigger I/O
Image pre-processing	Shading Correction (Offset and Gain)
	2 look-up tables (12-to-8 bit) on user-defined image region (Region-LUT)
Features	Greyscale resolution 12 bit / 10 bit / 8 bit
	Region of Interest (ROI)
	Up to 512 regions of interest (MROI)
	Test pattern (LFSR and grey level ramp)
	Image information and camera settings inside the image (status line)
	Crosshairs overlay on the image
	High blooming resistance
	Trigger input / Strobe output with programmable delay
	Image sensor and board temperature monitor
	Spare I/O’s for customization of board firmware

Table 3.1: Feature overview (see Chapter 4 for more information)

3.3 Technical Specification

Technical Parameters	OEM-D1312(I) Series
Technology	CMOS active pixel (APS)
Scanning system	Progressive scan
Optical format / diagonal	1" (13.6 mm diagonal) @ maximum resolution
	2/3" (11.6 mm diagonal) @ 1024 x 1024 resolution
Resolution	1312 x 1082 pixels
Pixel size	8 μm x 8 μm
Active optical area	10.48 mm x 8.64 mm (maximum)
Random noise	< 0.3 DN @ 8 bit [1)]
Fixed pattern noise (FPN)	3.4 DN @ 8 bit / correction OFF [1)]
Fixed pattern noise (FPN)	< 1DN @ 8 bit / correction ON [1)2)]
Dark current MV1-D1312	0.65 fA / pixel @ 27 °C
Dark current MV1-D1312I	0.79 fA / pixel @ 27 °C
Full well capacity	~ 100 ke$^-$
Spectral range MV1-D1312	350 nm ... 980 nm (see Fig. 3.1)
Spectral range MV1-D1312I	350 nm ... 1100 nm (see Fig. 3.2)
Responsivity MV1-D1312	295 x10^3 DN/(J/m^2) @ 670 nm / 8 bit
Responsivity MV1-D1312I	305 x10^3 DN/(J/m^2) @ 850 nm / 8 bit
Quantum Efficiency	> 50 %
Optical fill factor	> 60 %
Dynamic range	60 dB in linear mode, 120 dB with LinLog®
Colour format	Monochrome
Characteristic curve	Linear, LinLog®
Shutter mode	Global shutter
Greyscale resolution	12 bit / 10 bit / 8 bit

Table 3.2: General specification of the OEM-D1312(I) camera modules (Footnotes: [1)] Indicated values are typical values. [2)] Indicated values are subject to confirmation.)

Fig. 3.1 shows the quantum efficiency and the responsivity of the A1312 CMOS sensor, displayed as a function of wavelength. For more information on photometric and radiometric measurements see the Photonfocus application notes AN006 and AN008 available in the support area of our website www.photonfocus.com.
Fig. 3.2 shows the quantum efficiency and the responsivity of the A1312I CMOS sensor, displayed as a function of wavelength. The enhancement in the NIR quantum efficiency could be used to realize applications in the 900 to 1064 nm region.

	OEM-D1312(I)-40	OEM-D1312(I)-80	OEM-D1312(I)-160
Exposure Time	10 μs ... 1.68 s	10 μs ... 0.84 s	10 μs ... 0.42 s
Exposure time increment	100 ns	50 ns	25 ns
Frame rate[3)] (T_{int} = 10 μs)	27 fps	54 fps	108 fps
Pixel clock frequency	40 MHz	40 MHz	80 MHz
Pixel clock cycle	25 ns	25 ns	12.5 ns
Camera taps	1	2	2
Read out mode	sequential or simultaneous		

Table 3.3: Model-specific parameters (Footnote: [3)] Maximum frame rate @ full resolution)

	OEM1-D1312(I)-40	OEM-D1312(I)-80	OEM-D1312(I)-160
Operating temperature	0°C ... 50°C**		
Max. power consumption	< 2.3W	< 2.3W	>=2.3W
Dimensions OEM-A1312	44 x 44mm^2		
Dimensions OEM-ADCE-160-LVDS	53 x 43 mm^2		
Mass (sensor board + ADC board)	35 g		
Conformity	CE / RoHS / WEE		

*Table 3.4: Physical characteristics and operating ranges (**OEM modules with extended range of operating temperature on request)*

3.4 Customer board relevant configuration

The parameters and settings, which are essential to configure the customer board are shown in the following table. The timing of the camera is given in Section 4.1.2. A schematic of the dual tap assignment over the image is illustrated in Fig. 3.3.

	OEM-D1312(I)-40	OEM-D1312(I)-80	OEM-D1312(I)-160
Pixel Clock per Tap	40 MHz	40 MHz	80 MHz
Number of Taps	1	2	2
Greyscale resolution	12 bit / 10 bit / 8 bit	12 bit / 10 bit / 8 bit	12 bit / 10 bit / 8 bit
Line pause	36 clock cycles	18 clock cycles	18 clock cycles
CC1	EXSYNC	EXSYNC	EXSYNC
CC2	not used	not used	not used
CC3	not used	not used	not used
CC4	not used	not used	not used

Table 3.5: Summary of parameters needed for frame grabber configuration

Data resolution and data pin assignments are compliant with the CameraLink® standard (see [CL]).

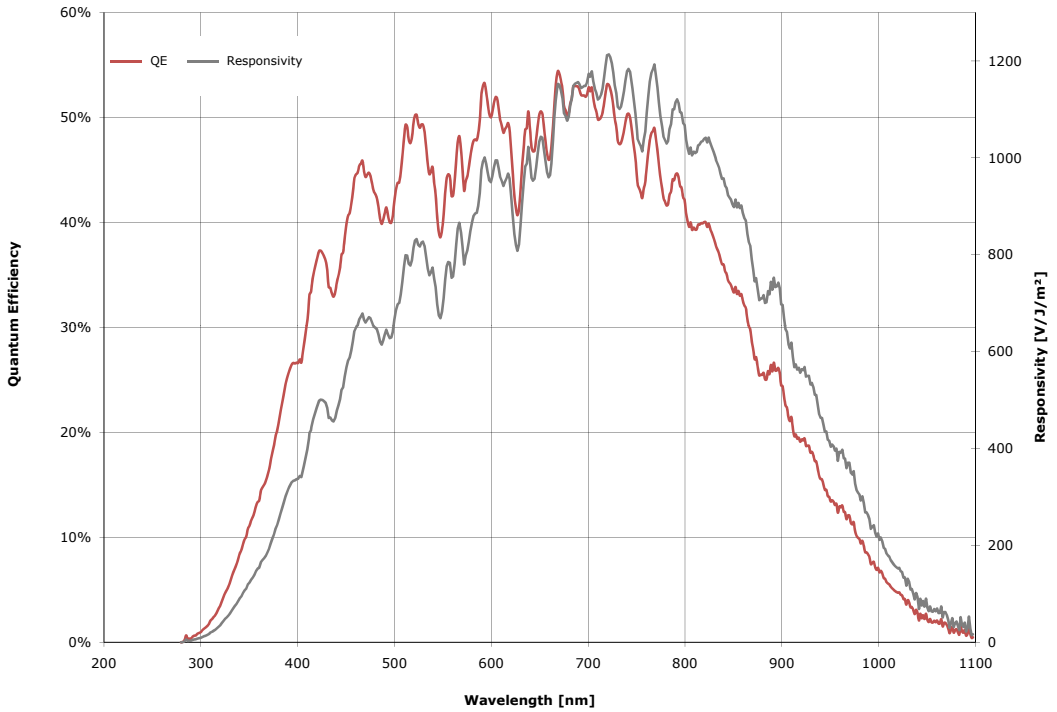


Figure 3.1: Spectral response of the A1312 CMOS image sensor (standard) in the OEM-D1312 camera module (Hint: the red-shiftet curve corresponds to the responsivity curve.)

Bit	Tap 0	Tap 0	Tap 0
	8 Bit	10 Bit	12 Bit
0 (LSB)	D0	D0	D0
1	D1	D1	D1
2	D2	D2	D2
3	D3	D3	D3
4	D4	D4	D4
5	D5	D5	D5
6	D6	D6	D6
7 (MSB of 8 Bit)	D7	D7	D7
8	-	D9	D8
9 (MSB of 10 Bit)	-	D10	D9
10	-	-	D10
11 (MSB of 12 Bit)	-	-	D11

Table 3.6: Data resolution and data pin assignments for the OEM-D1312(I)-40 camera module

"D0" in Table 3.7 corresponds to "DATA 0", "D1" corresponds to "DATA 1"and so forth (refer to Table 5.3).

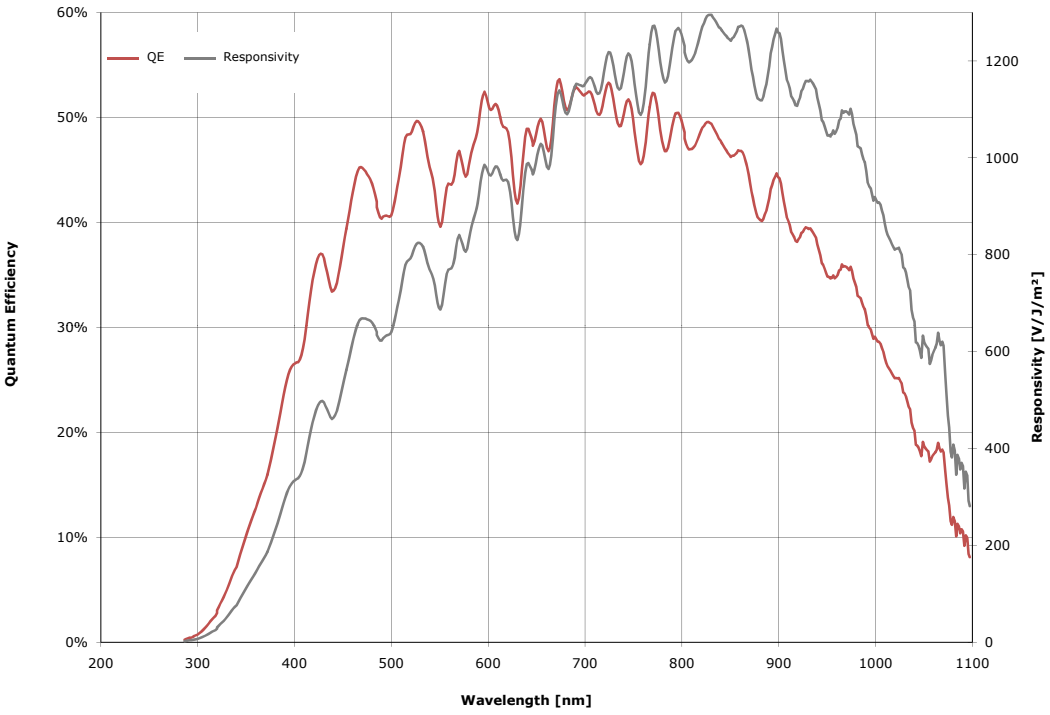


Figure 3.2: Spectral response of the A1312I image sensor (NIR enhanced) in the MV1-D1312I camera module (Hint: the red-shiftet curve corresponds to the responsivity curve.)

Bit	Tap 0	Tap 1	Tap 0	Tap 1	Tap 0	Tap 1
	8 Bit	8 Bit	10 Bit	10 Bit	12 Bit	12 Bit
0 (LSB)	A0	B0	A0	C0	A0	C0
1	A1	B1	A1	C1	A1	C1
2	A2	B2	A2	C2	A2	C2
3	A3	B3	A3	C3	A3	C3
4	A4	B4	A4	C4	A4	C4
5	A5	B5	A5	C5	A5	C5
6	A6	B6	A6	C6	A6	C6
7 (MSB of 8 Bit)	A7	B7	A7	C7	A7	C7
8	-	-	B0	B4	B0	B4
9 (MSB of 10 Bit)	-	-	B1	B5	B1	B5
10	-	-	-	-	B2	B6
11 (MSB of 12 Bit)	-	-	-	-	B3	B7

Table 3.7: Data resolution and data pin assignments for the OEM-D1312(I)-80 and for the OEM-D1312(I)-160 camera module

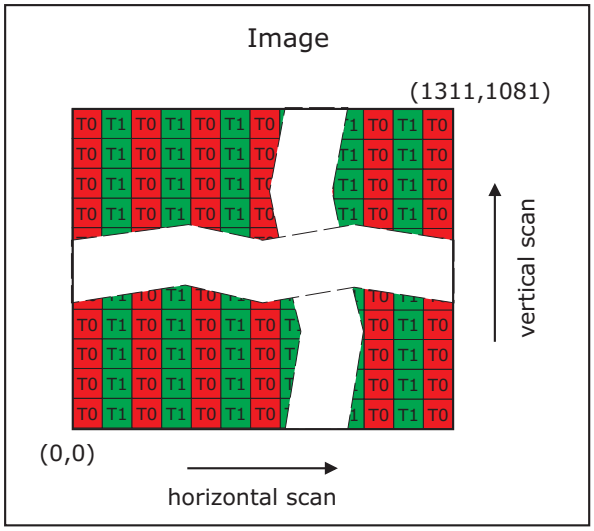


Figure 3.3: Schematic of the dual tap assignment over the image

4

Functionality

This chapter serves as an overview of the camera module configuration modes and explains camera features. The goal is to describe what can be done with the camera module. The setup of the MV1-D1312(I) series camera modules is explained in later chapters.

4.1 Image Acquisition

4.1.1 Readout Modes

The OEM camera module provide two different readout modes:

Sequential readout Frame time is the sum of exposure time and readout time. Exposure time of the next image can only start if the readout time of the current image is finished.

Simultaneous readout (interleave) The frame time is determined by the maximum of the exposure time or of the readout time, which ever of both is the longer one. Exposure time of the next image can start during the readout time of the current image.

Readout Mode	OEM-D1312(I)
Sequential readout	available
Simultaneous readout	available

Table 4.1: Readout mode of the OEM-D1312(I) camera module

The following figure illustrates the effect on the frame rate when using either the sequential readout mode or the simultaneous readout mode (interleave exposure).

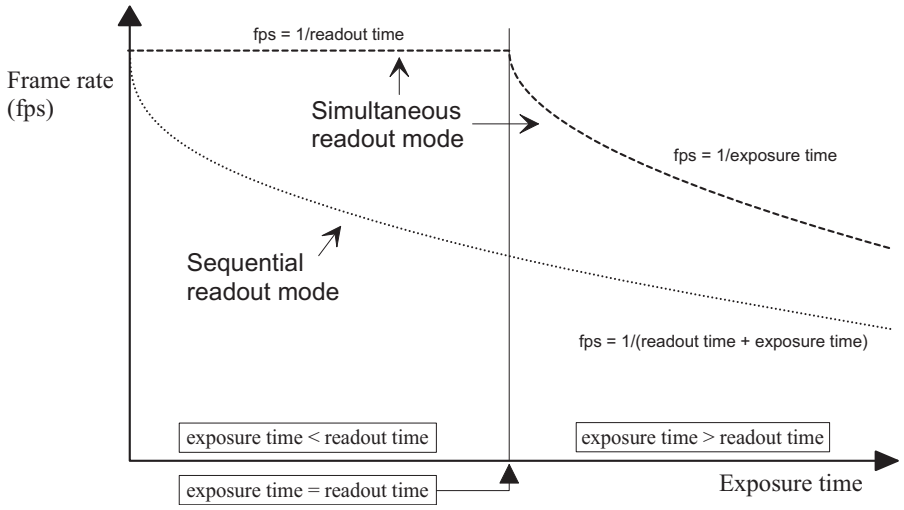


Figure 4.1: Frame rate in sequential readout mode and simultaneous readout mode

Sequential readout mode For the calculation of the frame rate only a single formula applies: frames per second equal to the inverse of the sum of exposure time and readout time.

Simultaneous readout mode (exposure time < readout time) The frame rate is given by the readout time. Frames per second equal to the inverse of the readout time.

Simultaneous readout mode (exposure time > readout time) The frame rate is given by the exposure time. Frames per second equal to the inverse of the exposure time.

The simultaneous readout mode allows higher frame rate. However, if the exposure time greatly exceeds the readout time, then the effect on the frame rate is neglectable.

In simultaneous readout mode image output faces minor limitations. The overall linear sensor reponse is partially restricted in the lower grey scale region.

When changing readout mode from sequential to simultaneous readout mode or vice versa, new settings of the BlackLevelOffset and of the image correction are required.

Sequential readout

By default the camera module continuously delivers images as fast as possible ("Free-running mode") in the sequential readout mode. Exposure time of the next image can only start if the readout time of the current image is finished.

Figure 4.2: Timing in free-running sequential readout mode

When the acquisition of an image needs to be synchronised to an external event, an external trigger can be used (refer to Section 4.4). In this mode, the camera module is idle until it gets a signal to capture an image.

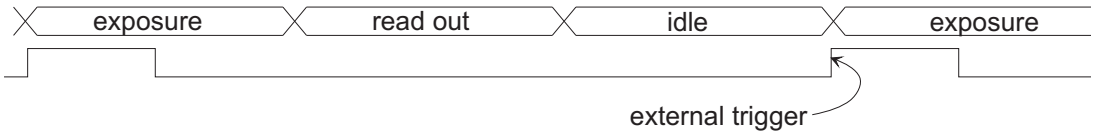


Figure 4.3: Timing in triggered sequential readout mode

Simultaneous readout (interleave exposure)

To achieve highest possible frame rates, the camera module must be set to "Free-running mode" with simultaneous readout. The camera module continuously delivers images as fast as possible. Exposure time of the next image can start during the readout time of the current image.
When the acquisition of an image needs to be synchronised to an external event, an external trigger can be used (refer to Section 4.4). In this mode, the camera module is idle until it gets a signal to capture an image.

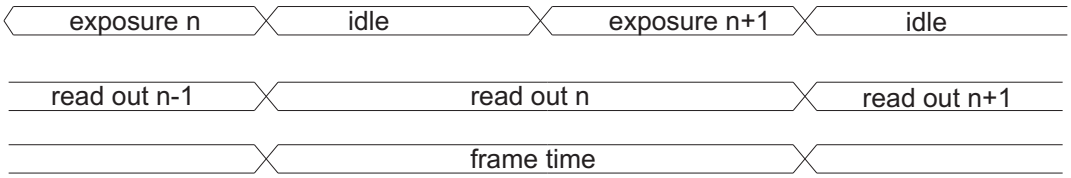


Figure 4.4: Timing in free-running simultaneous readout mode (readout time> exposure time)

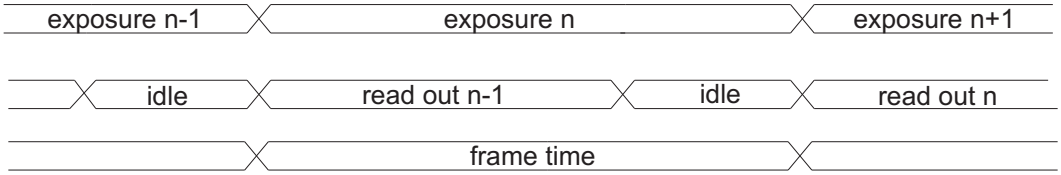


Figure 4.5: Timing in free-running simultaneous readout mode (readout time< exposure time)

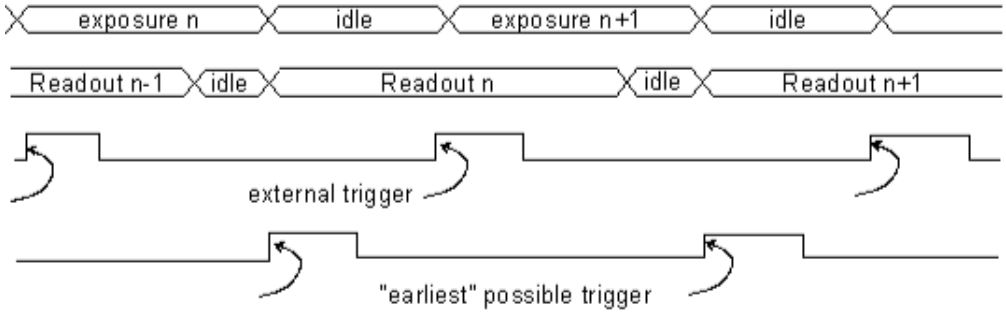


Figure 4.6: Timing in triggered simultaneous readout mode

4.1.2 Readout Timing

Sequential readout timing

By default, the camera module is in free running mode and delivers images without any external control signals. The sensor is operated in sequential readout mode, which means that the sensor is read out after the exposure time. Then the sensor is reset, a new exposure starts and the readout of the image information begins again. The data is output on the rising edge of the pixel clock. The signals FRAME_VALID (FVAL) and LINE_VALID (LVAL) mask valid image information. The signal SHUTTER indicates the active exposure period of the sensor and is shown for clarity only.

Simultaneous readout timing

To achieve highest possible frame rates, the camera module must be set to "Free-running mode" with simultaneous readout. The camera module continuously delivers images as fast as possible. Exposure time of the next image can start during the readout time of the current image. The data is output on the rising edge of the pixel clock. The signals FRAME_VALID (FVAL) and LINE_VALID (LVAL) mask valid image information. The signal SHUTTER indicates the active integration phase of the sensor and is shown for clarity only.

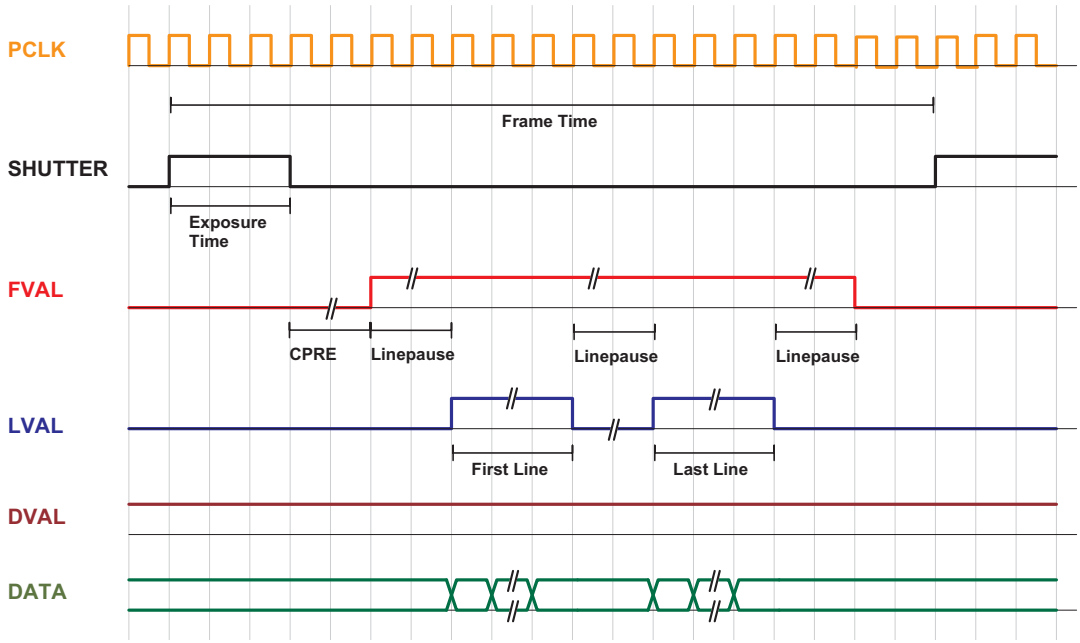


Figure 4.7: Timing diagram of sequential readout mode

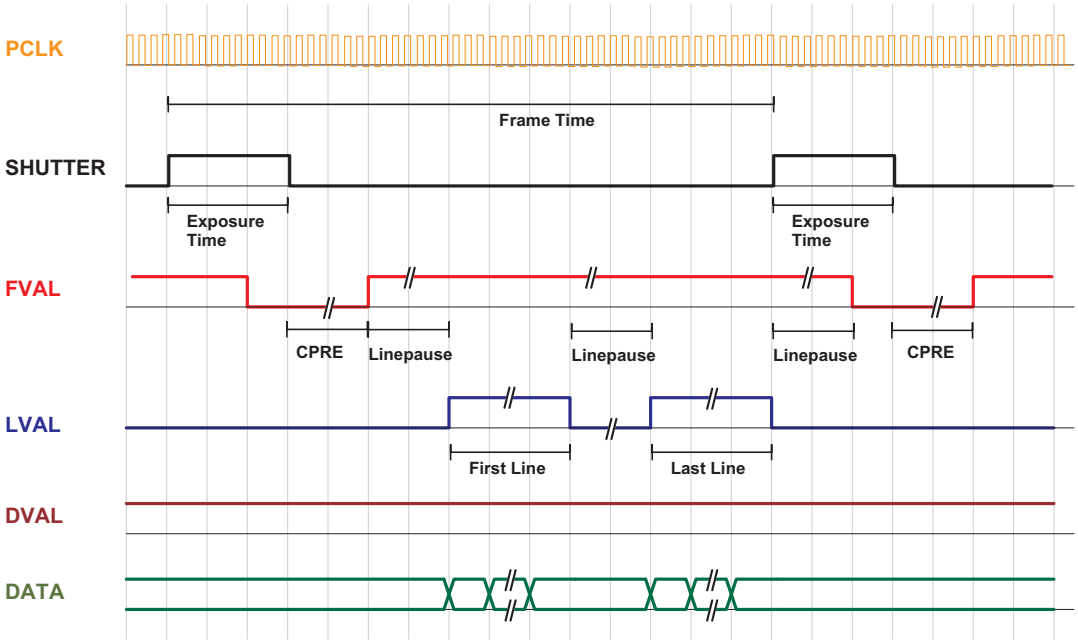


Figure 4.8: Timing diagram of simultaneous readout mode (readout time > exposure time)

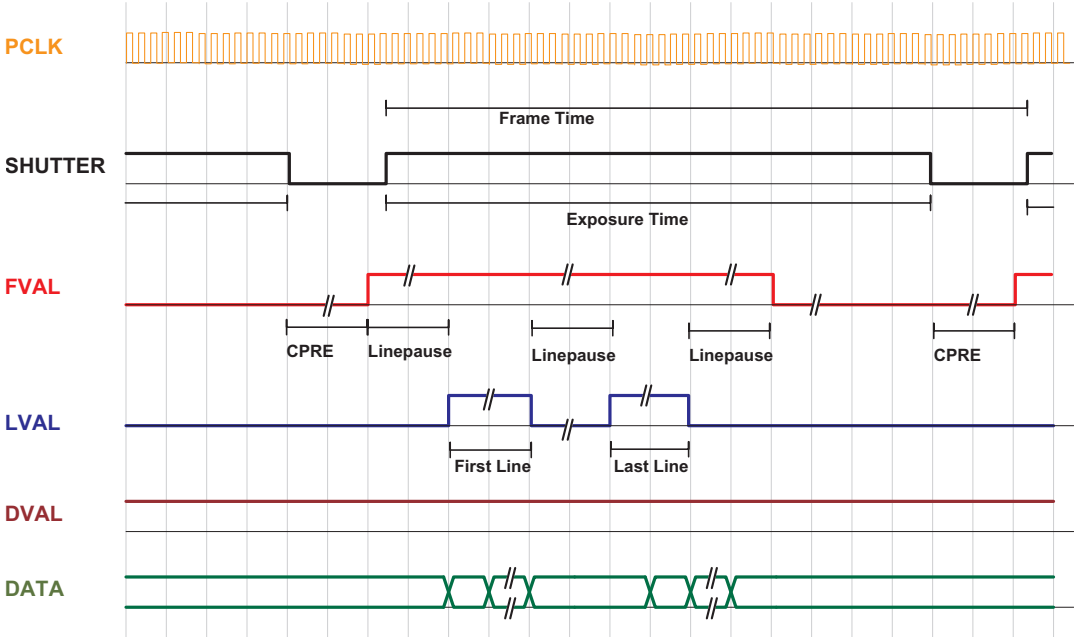


Figure 4.9: Timing diagram simultaneous readout mode (readout time < exposure time)

Frame time	Frame time is the inverse of the frame rate.
Exposure time	Period during which the pixels are integrating the incoming light.
PCLK	Pixel clock signal, named as PIXEL_CLK on PCB module connetor.
SHUTTER	Internal signal, shown only for clarity. Is 'high' during the exposure time.
FVAL (Frame Valid)	Is 'high' while the data of one complete frame are transferred.
LVAL (Line Valid)	Is 'high' while the data of one line are transferred. Example: To transfer an image with 640x480 pixels, there are 480 LVAL within one FVAL active high period. One LVAL lasts 640 pixel clock cycles.
DVAL (Data Valid)	Is 'high' while data are valid.
DATA	Transferred pixel values. Example: For a 100x100 pixel image, there are 100 values transferred within one LVAL active high period, or 100*100 values within one FVAL period.
Line pause	Delay before the first line and after every following line when reading out the image data.

Table 4.2: Explanation of control and data signals used in the timing diagram

These terms will be used also in the timing diagrams of Section 4.4.

4.1.3 Exposure Control

The exposure time defines the period during which the image sensor integrates the incoming light. Refer to Table 3.3 for the allowed exposure time range.

4.1.4 Maximum Frame Rate

The maximum frame rate depends on the exposure time and the size of the image (see Section 4.3.)

4.2 Pixel Response

4.2.1 Linear Response

The camera module offers a linear response between input light signal and output grey level. This can be modified by the use of LinLog®as described in the following sections. In addition, a linear digital gain may be applied, as follows. Please see Table 3.2 for more model-dependent information.

Black Level Adjustment

The black level is the average image value at no light intensity. It can be adjusted by the software by changing the black level offset. Thus, the overall image gets brighter or darker. Use a histogram to control the settings of the black level.

4.2.2 LinLog®

Overview

The LinLog® technology from Photonfocus allows a logarithmic compression of high light intensities inside the pixel. In contrast to the classical non-integrating logarithmic pixel, the LinLog® pixel is an integrating pixel with global shutter and the possibility to control the transition between linear and logarithmic mode.
In situations involving high intrascene contrast, a compression of the upper grey level region can be achieved with the LinLog® technology. At low intensities each pixel shows a linear response. At high intensities the response changes to logarithmic compression (see Fig. 4.10). The transition region between linear and logarithmic response can be smoothly adjusted by software and is continuously differentiable and monotonic.

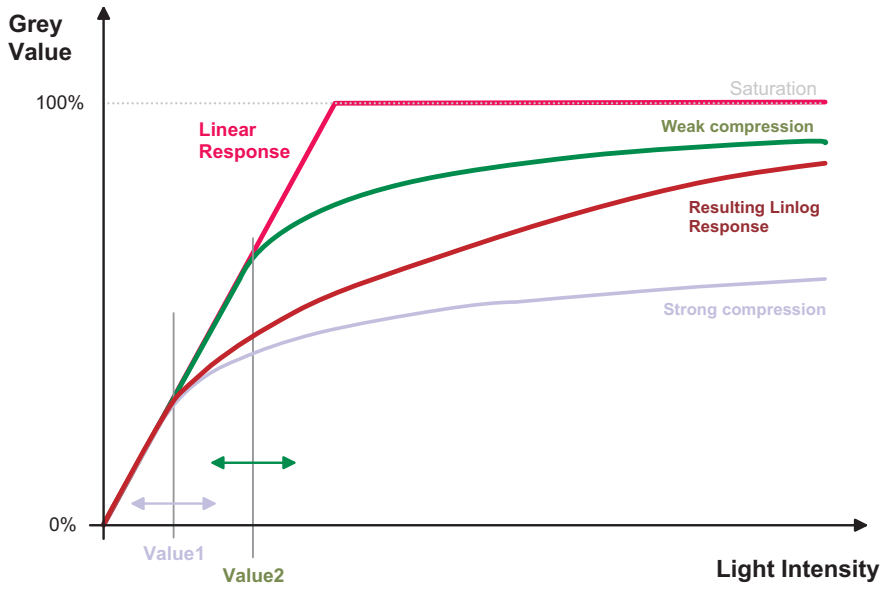


Figure 4.10: Resulting LinLog2 response curve

LinLog® is controlled by up to 4 parameters (`Time1`, `Time2`, `Value1` and `Value2`). `Value1` and `Value2` correspond to the LinLog® voltage that is applied to the sensor. The higher the parameters `Value1` and `Value2` respectively, the stronger the compression for the high light intensities. `Time1`

and Time2 are normalised to the exposure time. They can be set to a maximum value of 1000, which corresponds to the exposure time.
Examples in the following sections illustrate the LinLog® feature.

LinLog1

In the simplest way the pixels are operated with a constant LinLog® voltage which defines the knee point of the transition.This procedure has the drawback that the linear response curve changes directly to a logarithmic curve leading to a poor grey resolution in the logarithmic region (see Fig. 4.12).

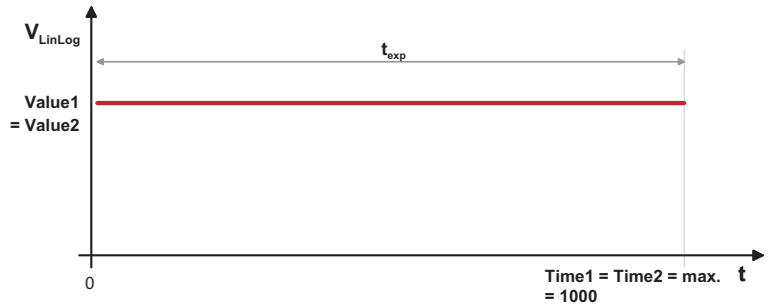


Figure 4.11: Constant LinLog voltage in the Linlog1 mode

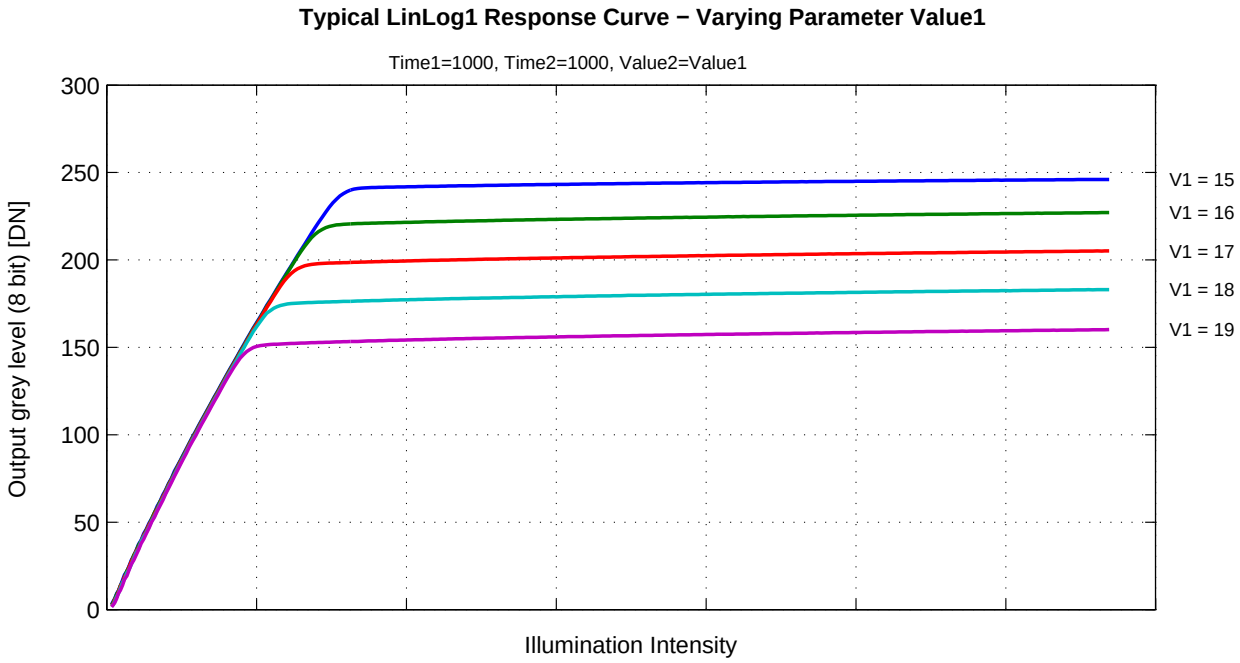


Figure 4.12: Response curve for different LinLog settings in LinLog1 mode

LinLog2

To get more grey resolution in the LinLog® mode, the LinLog2 procedure was developed. In LinLog2 mode a switching between two different logarithmic compressions occurs during the exposure time (see Fig. 4.13). The exposure starts with strong compression with a high LinLog®voltage (`Value1`). At `Time1` the LinLog®voltage is switched to a lower voltage resulting in a weaker compression. This procedure gives a LinLog®response curve with more grey resolution. Fig. 4.14 and Fig. 4.15 show how the response curve is controlled by the three parameters `Value1`, `Value2` and the LinLog®time `Time1`.

Settings in LinLog2 mode, enable a fine tuning of the slope in the logarithmic region.

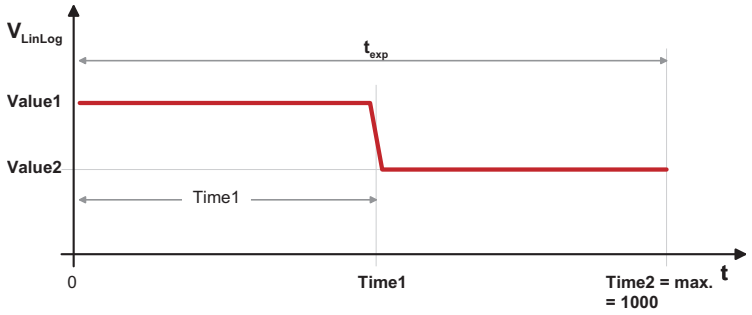


Figure 4.13: Voltage switching in the Linlog2 mode

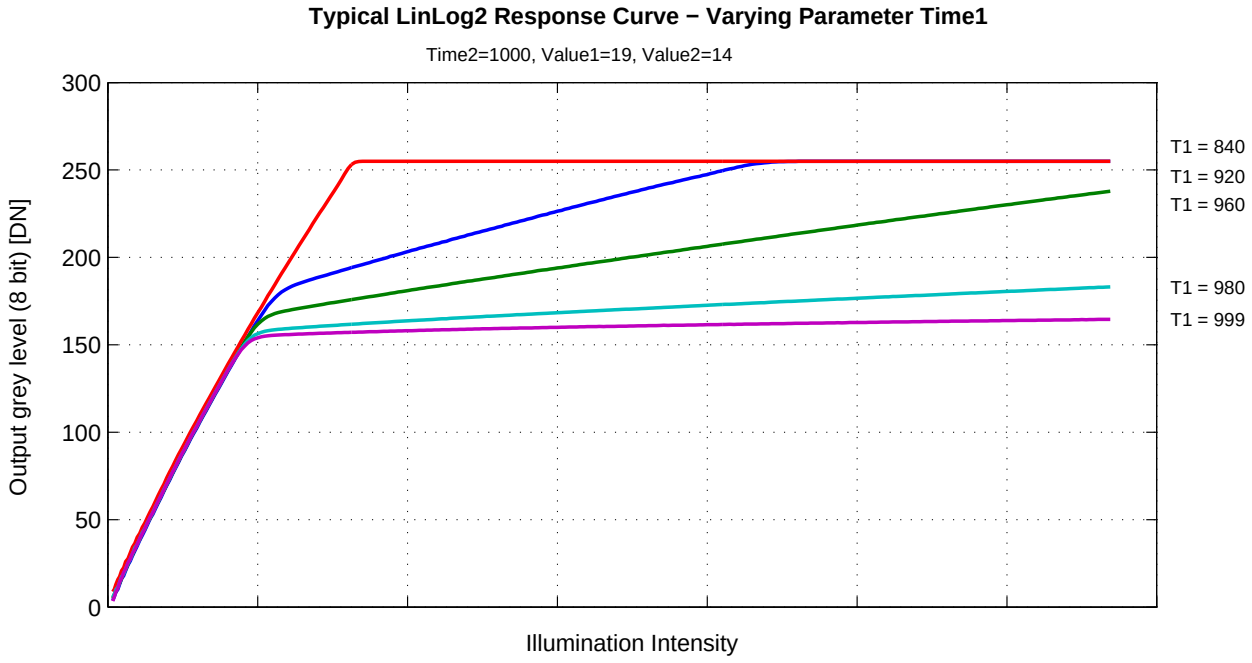


Figure 4.14: Response curve for different LinLog settings in LinLog2 mode

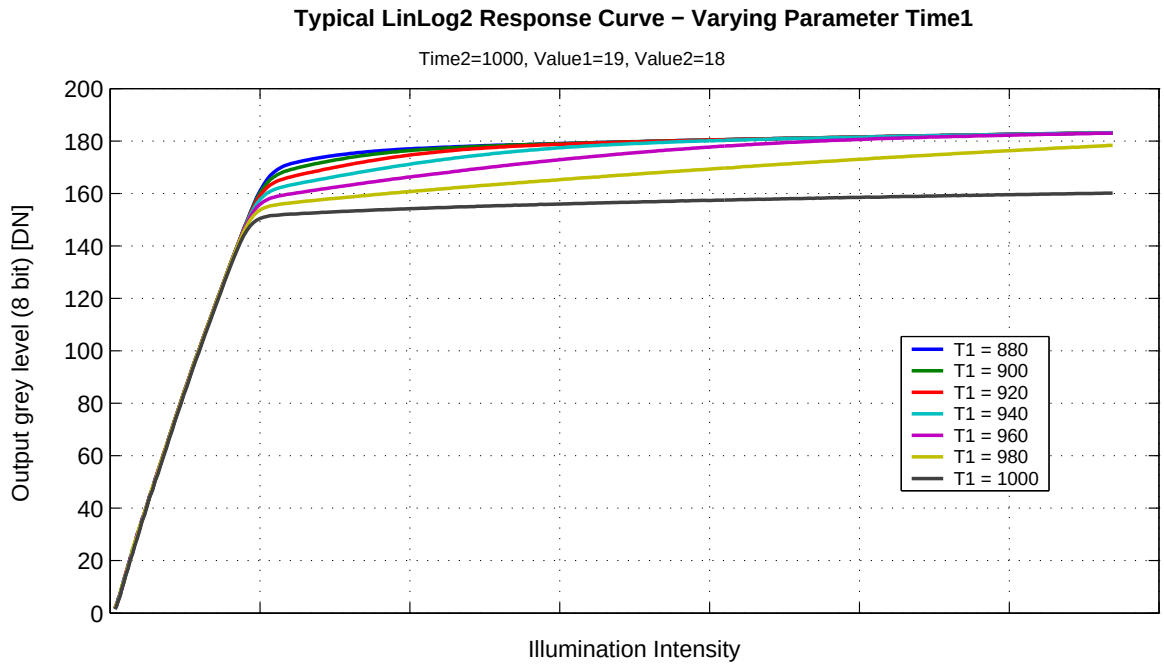


Figure 4.15: Response curve for different LinLog settings in LinLog2 mode

LinLog3

To enable more flexibility the LinLog3 mode with 4 parameters was introduced. Fig. 4.16 shows the timing diagram for the LinLog3 mode and the control parameters.

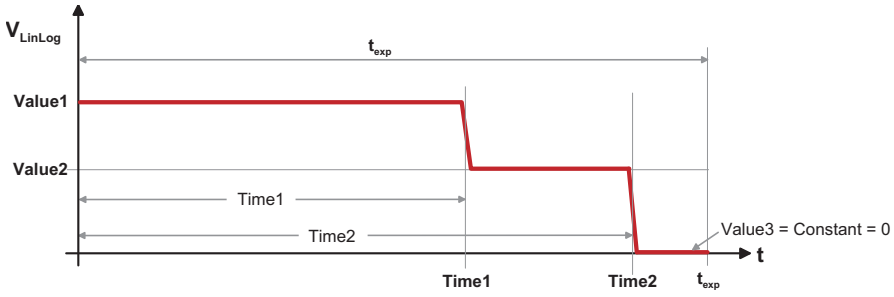


Figure 4.16: Voltage switching in the LinLog3 mode

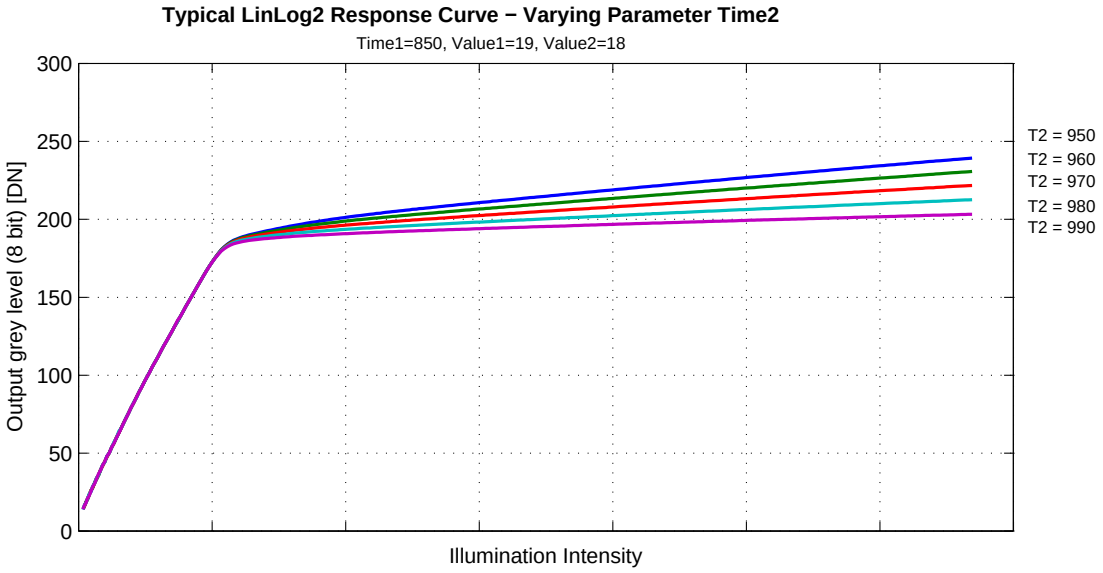


Figure 4.17: Response curve for different LinLog settings in LinLog3 mode

4.3 Reduction of Image Size

With Photonfocus camera modules there are several possibilities to focus on the interesting parts of an image, thus reducing the data rate and increasing the frame rate. The most commonly used feature is Region of Interest (ROI).

4.3.1 Region of Interest (ROI)

Some applications do not need full image resolution (e.g. 1312 x 1082 pixels). By reducing the image size to a certain region of interest (ROI), the frame rate can be drastically increased. A region of interest can be almost any rectangular window and is specified by its position within the full frame and its width (W) and height (H). Fig. 4.18, Fig. 4.19 and Fig. 4.20 show possible configurations for the region of interest, and Table 4.3 presents numerical examples of how the frame rate can be increased by reducing the ROI.

Both reductions in x- and y-direction result in a higher frame rate.

The minimum width of the region of interest depends on the model of the OEM-D1312(I) camera module series. For more details please consult Table 4.4 and Table 4.5.

The minimum width must be positioned symmetrically towards the vertical center line of the sensor as shown in Fig. 4.18, Fig. 4.19 and Fig. 4.20). A list of possible settings of the ROI for each camera model is given in Table 4.5.

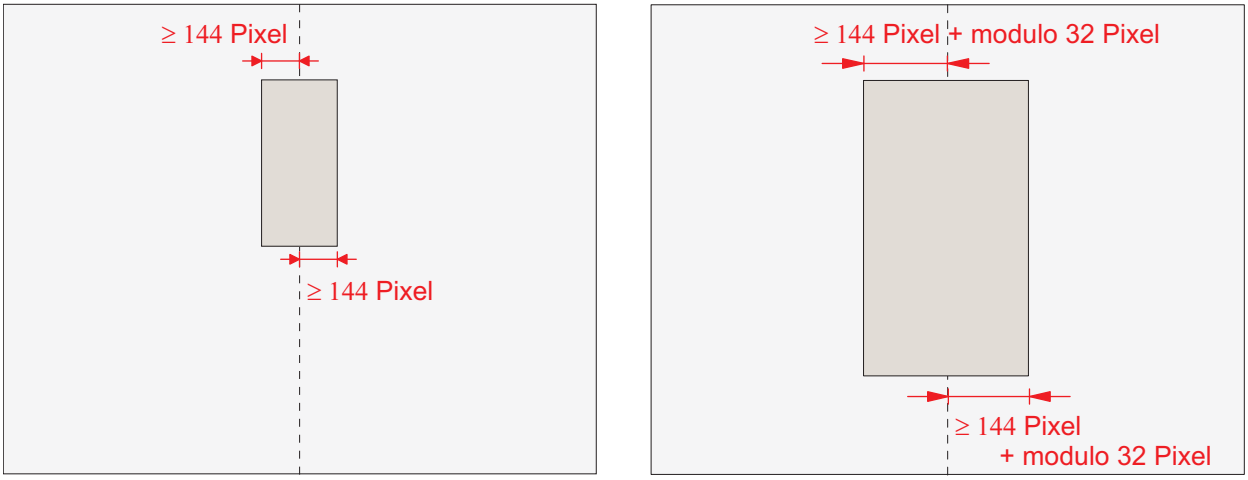


Figure 4.18: Possible configuration of the region of interest for the OEM-D1312(I)-40 CMOS module

It is recommended to re-adjust the settings of the shading correction each time a new region of interest is selected.

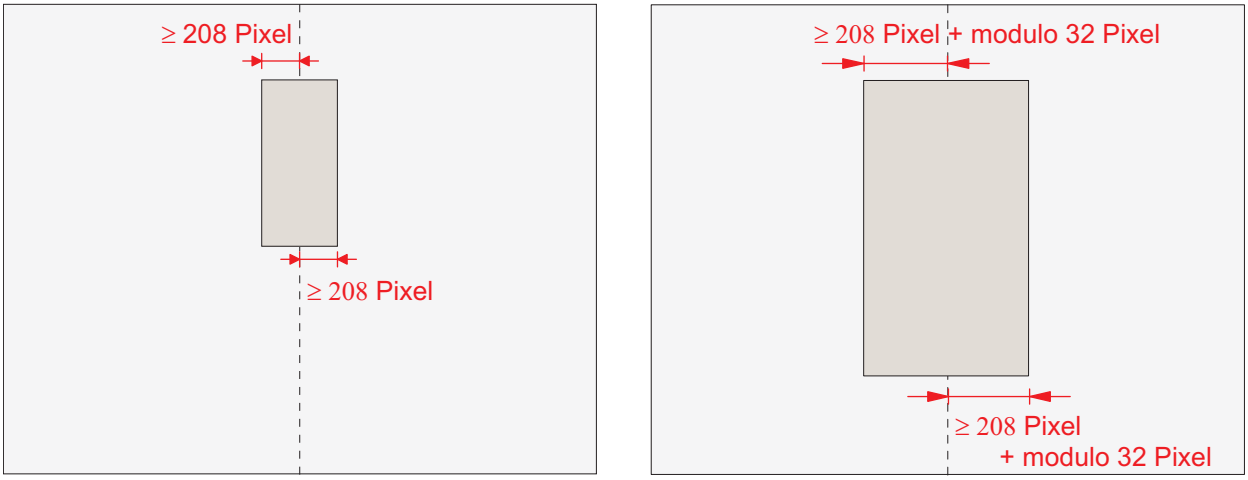


Figure 4.19: Possible configuration of the region of interest with OEM-D1312(I)-80 CMOS module

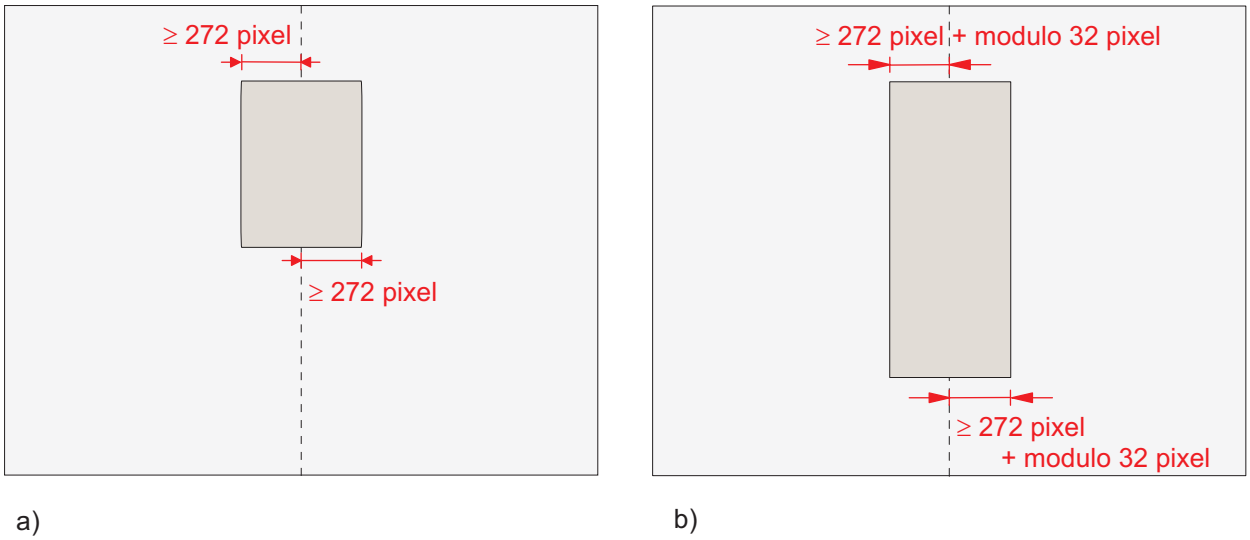


Figure 4.20: Possible configuration of the region of interest with OEM-D1312(I)-160 CMOS module

Any region of interest may NOT be placed outside of the center of the sensor. Examples shown in Fig. 4.21 illustrate configurations of the ROI that are NOT allowed.

ROI Dimension [Standard]	OEM-D1312(I)-40	OEM-D1312(I)-80	OEM-D1312(I)-160
1312 x 1082 (full resolution)	27 fps	54 fps	108 fps
288 x 1 (minimum resolution)	10245 fps	10863 fps	not allowed ROI setting
1280 x 1024 (SXGA)	29 fps	58 fps	117 fps
1280 x 768 (WXGA)	39 fps	78 fps	156 fps
800 x 600 (SVGA)	79 fps	157 fps	310 fps
640 x 480 (VGA)	121 fps	241 fps	472 fps
544 x 1	9615 fps	10498 fps	11022 fps
544 x 1082	63 fps	125 fps	249 fps
1312 x 544	54 fps	107 fps	214 fps
1312 x 256	114 fps	227 fps	445 fps
544 x 544	125 fps	248 fps	485 fps
1024 x 1024	36 fps	72 fps	145 fps
1312 x 1	8116 fps	9537 fps	10468 fps

Table 4.3: Frame rates of different ROI settings (exposure time 10 µs; correction on, and sequential readout mode).

Figure 4.21: ROI configuration examples that are NOT allowed

4.3.2 ROI configuration

In the OEM-D1312(I) camera module series the following two restrictions have to be respected for the ROI configuration:

- The minimum width (w) of the ROI is camera module model dependent, consisting of 288 pixel in the OEM-D1312(I)-40 camera module, of 416 pixel in the OEM-D1312(I)-80 camera module and of 544 pixel in the OEM-D1312(I)-80 camera module.

- The region of interest must overlap a minimum number of pixels centered to the left and to the right of the vertical middle line of the sensor (ovl).

For any camera module model of the OEM-D1312(I) camera module series the allowed ranges for the ROI settings can be deduced by the following formula:

$$x_{min} = \max(0, 656 + ovl - w)$$
$$x_{max} = \min(656 - ovl, 1312 - w)$$

where "ovl" is the overlap over the middle line and "w" is the width of the region of interest.

Any ROI settings in x-direction exceeding the minimum ROI width must be modulo 32.

	OEM-D1312(I)-40	OEM-D1312(I)-80	OEM-D1312(I)-160
ROI width (w)	288 ... 1312	416 ... 1312	544 ... 1312
overlap (ovl)	144	208	272
width condition	modulo 32	modulo 32	modulo 32

Table 4.4: Summary of the ROI configuration restrictions for the OEM-D1312(I) camera series indicating the minimum ROI width (w) and the required number of pixel overlap (ovl) over the sensor middle line

The settings of the region of interest in x-direction are restricted to modulo 32 (see Table 4.5).

There are no restrictions for the settings of the region of interest in y-direction.

4.3.3 Calculation of the maximum frame rate

The frame rate mainly depends on the exposure time and readout time. The frame rate is the inverse of the frame time.
fps $= \frac{1}{t_{frame}}$

Calculation of the frame time (sequential mode)

$$t_{frame} \geq t_{exp} + t_{ro}$$

Typical values of the readout time t_{ro} are given in table Table 4.6. **Calculation of the frame time (simultaneous mode)**

The calculation of the frame time in simultaneous read out mode requires more detailed data input and is skipped here for the purpose of clarity.

The formula for the calculation of the frame time in simultaneous mode is available from Photonfocus on request.

Width	ROI-X (OEM-D1312(I)-40)	ROI-X (OEM-D1312(I)-80)	ROI-X (OEM-D1312(I)-160)
288	512	not available	not available
320	480 ... 512	not available	not available
352	448 ... 512	not available	not available
384	416 ... 512	not available	not available
416	384 ... 512	448	not available
448	352 ... 512	416 ... 448	not available
480	320 ... 520	384 ... 448	not available
512	288 ... 512	352 ... 448	not available
544	256 ...512	320 ... 448	384
576	224 ... 512	288 ... 448	352 ... 384
608	192 ... 512	256 ... 448	320 ... 352
640	160 ... 512	224 ... 448	288 ... 384
672	128 ... 512	192 ... 448	256 ... 384
704	96 ... 512	160 ... 448	224 ... 384
736	64 ... 512	128 ... 448	192 ... 384
768	32 ... 512	96 ... 448	160 ... 384
800	0 ... 512	64 ... 448	128 ... 384
832	0 ... 480	32 ... 448	96 ... 384
864	0 ... 448	0 ... 448	64 ... 384
896	0 ... 416	0 ... 416	32 ... 384
...	...	...	...
1312	0	0	0

Table 4.5: Some possible ROI-X settings

ROI Dimension	OEM-D1312(I)-40	OEM-D1312(I)-80	OEM-D1312(I)-160
1312 x 1082	t_{ro} = 36.46 ms	t_{ro}= 18.23 ms	t_{ro} = 9.12 ms
1024 x 512	t_{ro} = 13.57 ms	t_{ro}= 6.78 ms	t_{ro} = 3.39 ms
1024 x 256	t_{ro} = 6.78 ms	t_{ro}= 3.39 ms	t_{ro} = 1.70 ms

Table 4.6: Read out time at different ROI settings for the OEM-D1312(I) CMOS camera module series in sequential read out mode.

A frame rate calculator for calculating the maximum frame rate is available in the support area of the Photonfocus website.

An overview of resulting frame rates in different exposure time settings is given in table Table 4.7.

Exposure time	OEM-D1312(I)-40	OEM-D1312(I)-80	OEM-D1312(I)-160
10 μs	27 / 27 fps	54 / 54 fps	108 / 108 fps
100 μs	27 / 27 fps	54 / 54 fps	107 / 108 fps
500 μs	27 / 27 fps	53 / 54 fps	103 / 108 fps
1 ms	27 / 27 fps	51 / 54 fps	98 / 108 fps
2 ms	26 / 27 fps	49 / 54 fps	89 / 108 fps
5 ms	24 / 27 fps	42 / 54 fps	70 / 108 fps
10 ms	22 / 27 fps	35 / 54 fps	52 / 99 fps
12 ms	21 / 27 fps	33 / 54 fps	47 / 82 fps

Table 4.7: Frame rates of different exposure times, [sequential readout mode / simultaneous readout mode], resolution 1312 x 1082 pixel (correction on).

4.3.4 Multiple Regions of Interest

The OEM-D1312(I) camera module series can handle up to 512 different regions of interest. This feature can be used to reduce the image data and increase the frame rate. An application example for using multiple regions of interest (MROI) is a laser triangulation system with several laser lines. The multiple ROIs are joined together and form a single image, which is transferred to the frame grabber.
An individual MROI region is defined by its starting value in y-direction and its height. The starting value in horizontal direction and the width is the same for all MROI regions and is defined by the ROI settings. The maximum frame rate in MROI mode depends on the number of rows and columns being read out. Overlapping ROIs are allowed. See Section 4.3.3 for information on the calculation of the maximum frame rate.
Fig. 4.22 compares ROI and MROI: the setups (visualized on the image sensor area) are displayed in the upper half of the drawing. The lower half shows the dimensions of the resulting image. On the left-hand side an example of ROI is shown and on the right-hand side an example of MROI. It can be readily seen that resulting image with MROI is smaller than the resulting image with ROI only and the former will result in an increase in image frame rate.
Fig. 4.23 shows another MROI drawing illustrating the effect of MROI on the image content.
Fig. 4.24 shows an example from hyperspectral imaging where the presence of spectral lines at known regions need to be inspected. By using MROI only a 656x54 region need to be readout and a frame rate of 4300 fps can be achieved. Without using MROI the resulting frame rate would be 216 fps for a 656x1082 ROI.

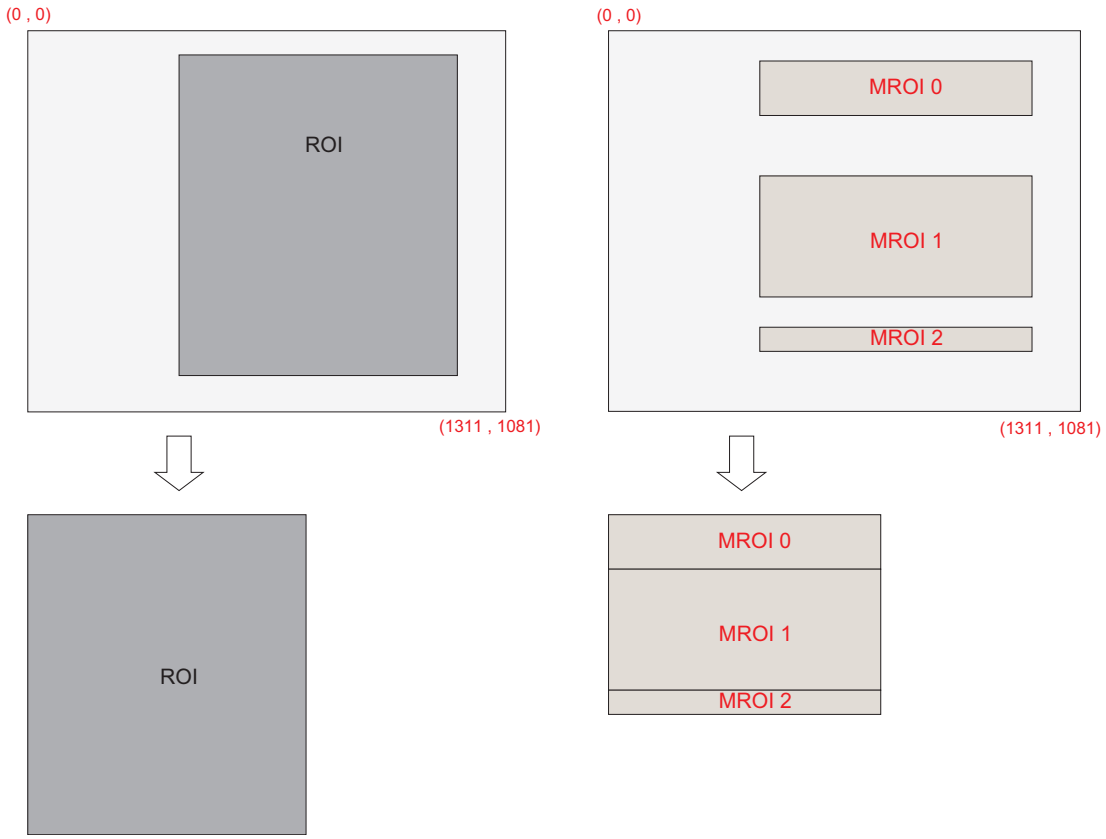


Figure 4.22: Multiple Regions of Interest

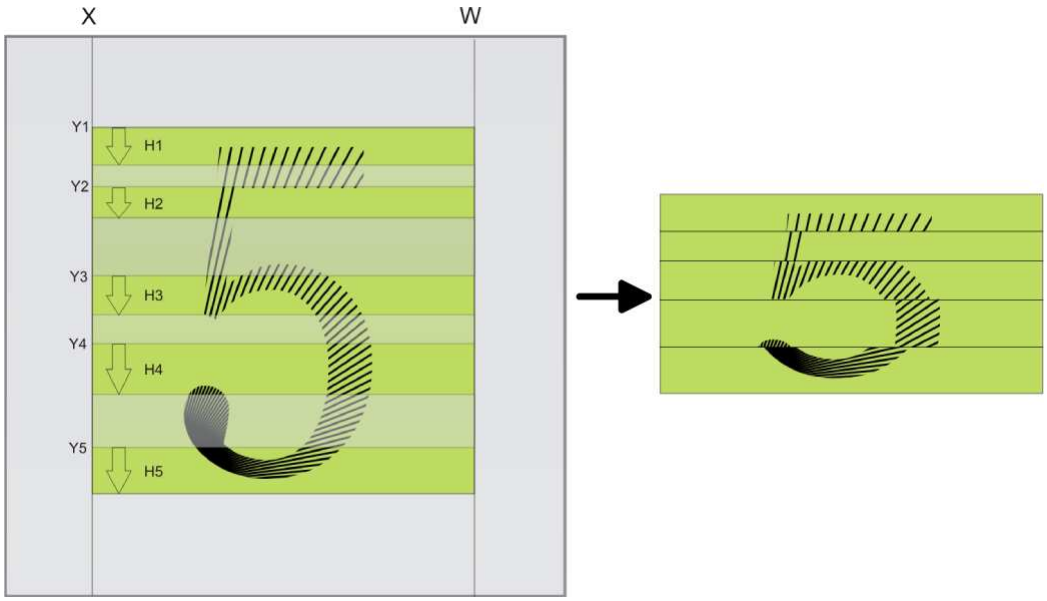


Figure 4.23: Multiple Regions of Interest with 5 ROIs

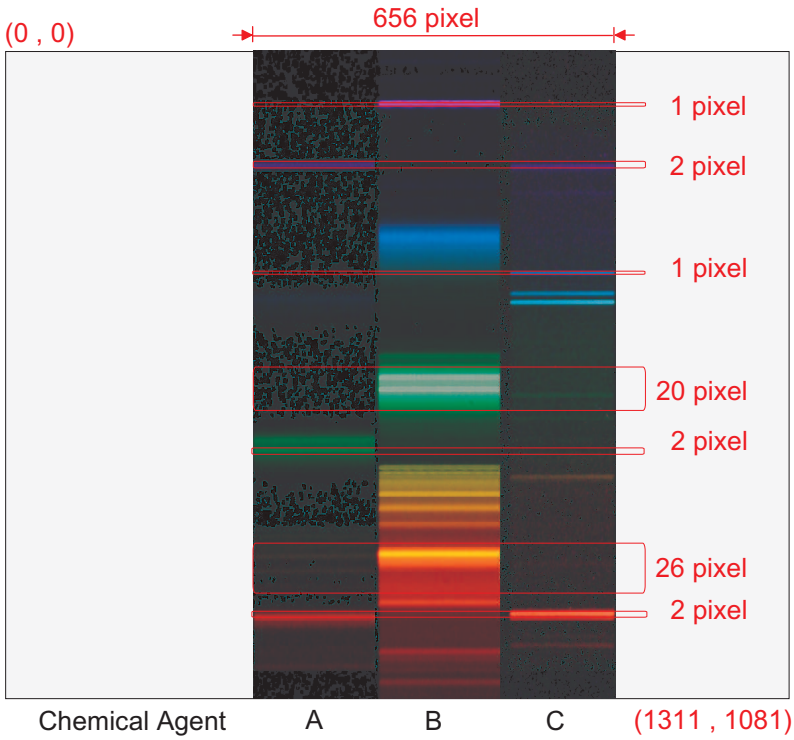


Figure 4.24: Multiple Regions of Interest in hyperspectral imaging

4.3.5 Decimation

Decimation reduces the number of pixels in y-direction. Decimation can also be used together with ROI or MROI. Decimation in y-direction transfers every n^{th} row only and directly results in reduced read-out time and higher frame rate respectively.
Fig. 4.25 shows decimation on the full image. The rows that will be read out are marked by red lines. Row 0 is read out and then every n^{th} row.

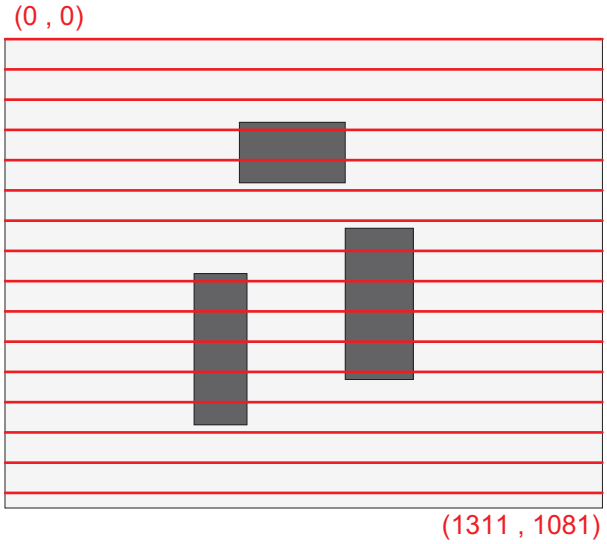


Figure 4.25: Decimation in full image

Fig. 4.26 shows decimation on a ROI. The row specified by the Window.Y setting is first read out and then every n^{th} row until the end of the ROI.

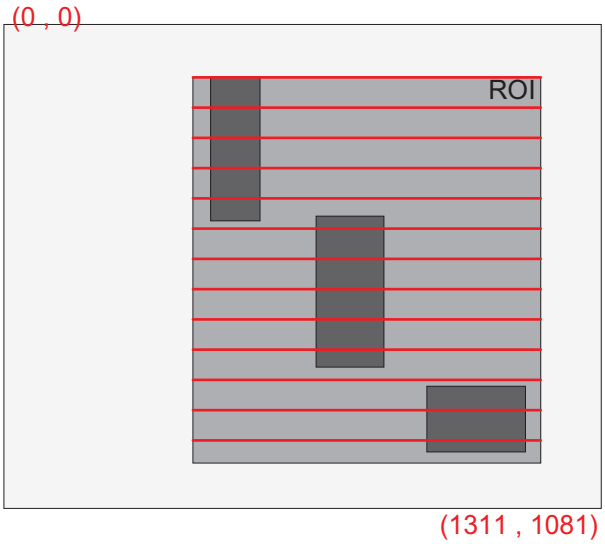


Figure 4.26: Decimation and ROI

Fig. 4.27 shows decimation and MROI. For every MROI region m, the first row read out is the row specified by the MROI<m>.Y setting and then every n^{th} row until the end of MROI region m.

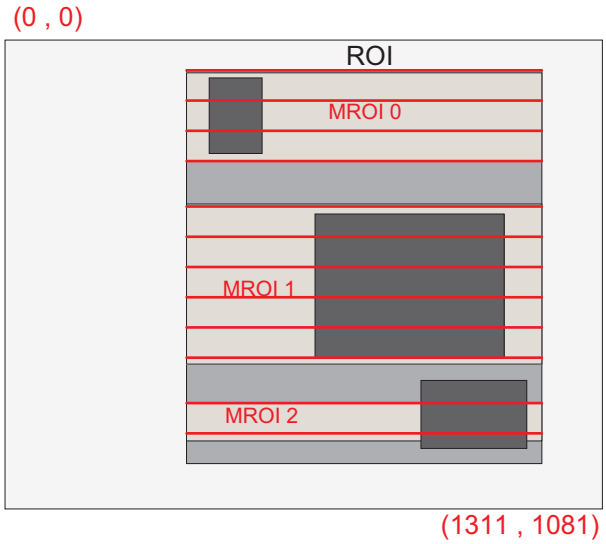


Figure 4.27: Decimation and MROI

The image in Fig. 4.28 on the right-hand side shows the result of decimation 3 of the image on the left-hand side.

Figure 4.28: Image example of decimation 3

An example of a high-speed measurement of the elongation of an injection needle is given in Fig. 4.29. In this application the height information is less important than the width information. Applying decimation 2 on the original image on the left-hand side doubles the resulting frame to about 7800 fps.

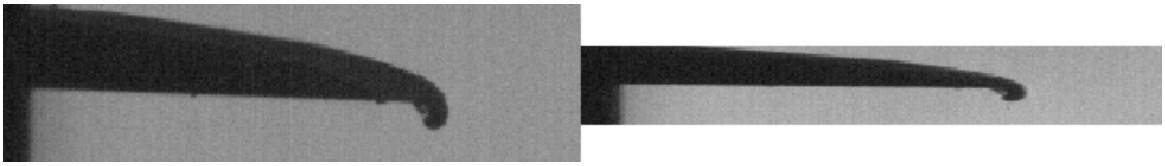


Figure 4.29: Example of decimation 2 on image of injection needle

4.4 Trigger and Strobe

4.4.1 Introduction

The start of the exposure of the image sensor is controlled by the trigger. The trigger can either be generated internally by the camera module (free running trigger mode) or by an external device (external trigger mode).
This section refers to the external trigger mode if not otherwise specified.
In external trigger mode, the trigger can be applied through the PCB connector. CC1 signal (interface trigger) or TRIGGERsignal (I/O Trigger) (see Section 4.4.2). The trigger signal can be configured to be active high or active low. When the frequency of the incoming triggers is higher than the maximal frame rate of the current camera module settings, then some trigger pulses will be missed. A missed trigger counter counts these events. This counter can be read out by the user.
The exposure time in external trigger mode can be defined by the setting of the exposure time register (camera controlled exposure mode) or by the width of the incoming trigger pulse (trigger controlled exposure mode) (see Section 4.4.3).
An external trigger pulse starts the exposure of one image. In Burst Trigger Mode however, a trigger pulse starts the exposure of a user defined number of images (see Section 4.4.5).
The start of the exposure is shortly after the active edge of the incoming trigger. An additional trigger delay can be applied that delays the start of the exposure by a user defined time (see Section 4.4.4). This often used to start the exposure after the trigger to a flash lighting source.

4.4.2 Trigger Source

The trigger signal can be configured to be active high or active low. One of the following trigger sources can be used:

Free running The trigger is generated internally by the camera module. Exposure starts immediately after the camera module is ready and the maximal possible frame rate is attained, if Constant Frame Rate mode is disabled. In Constant Frame Rate mode, exposure starts after a user-specified time (Frame Time) has elapsed from the previous exposure start and therefore the frame rate is set to a user defined value.

Interface Trigger In interface trigger mode, the trigger signals applied on CC1 (Pin 59 of OEM camera module PCB connector) will be accepted to start a new image acquisition. interface.

I/O Trigger In the I/O trigger mode, the trigger signals applied on TRIGGER (Pin 67 of OEM camera module PCB connector) will be accepted to start a new image acquisition.

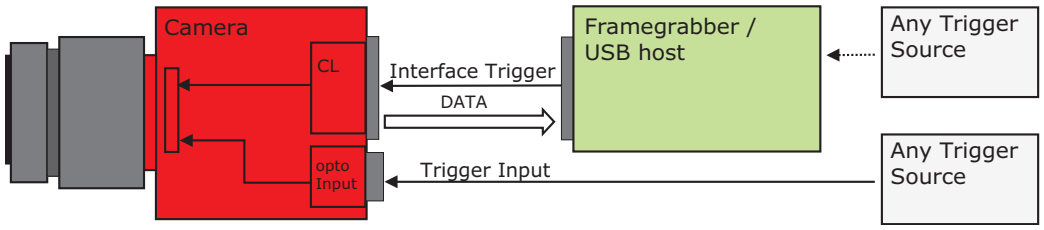


Figure 4.30: Trigger inputs of the OEM camera modules, demonstrated here for clarity in the context of a camera vision system

4.4.3 Exposure Time Control

Depending on the trigger mode, the exposure time can be determined either by the camera module or by the trigger signal itself:

Camera-controlled Exposure time In this trigger mode the exposure time is defined by the camera module. For an active high trigger signal, the camera module starts the exposure with a positive trigger edge and stops it when the preprogrammed exposure time has elapsed. The exposure time is defined by the software.

Trigger-controlled Exposure time In this trigger mode the exposure time is defined by the pulse width of the trigger pulse. For an active high trigger signal, the camera module starts the exposure with the positive edge of the trigger signal and stops it with the negative edge.

Trigger-controlled exposure time is not available in simultaneous readout mode.

We do not recommend to use the Level-controlled Exposure because some features can not be supported in this mode.

External Trigger with Camera module controlled Exposure Time

In the external trigger mode with camera module controlled exposure time the rising edge of the trigger pulse starts the camera module states machine, which controls the sensor and optional an external strobe output. Fig. 4.31 shows the detailed timing diagram for the external trigger mode with camera module controlled exposure time.

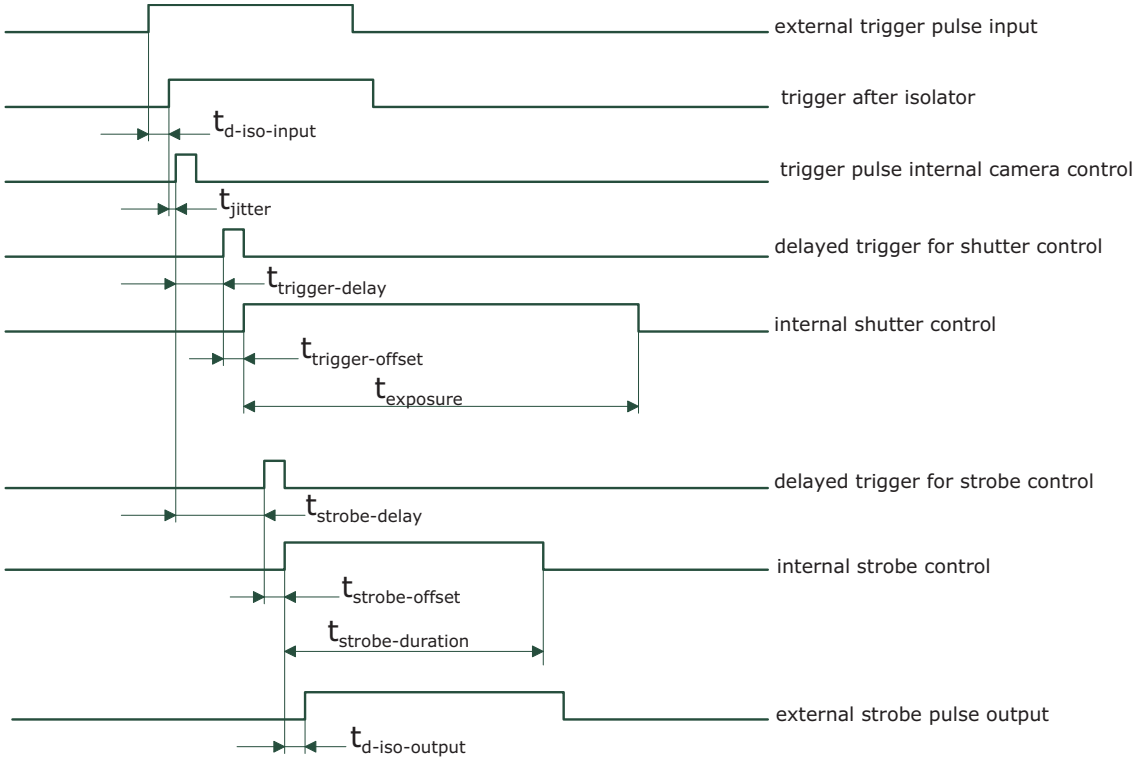


Figure 4.31: Timing diagram for the camera module controlled exposure time

The rising edge of the trigger signal is detected in the camera module control electronic which is implemented in an FPGA. Before the trigger signal reaches the FPGA it is isolated from the camera module environment to allow robust integration of the camera module into the vision system. In the signal isolator the trigger signal is delayed by time $t_{d-iso-input}$. This signal is clocked into the FPGA which leads to a jitter of t_{jitter}. The pulse can be delayed by the time $t_{trigger-delay}$ which can be configured by a user defined value via camera module software. The trigger offset delay $t_{trigger-offset}$ results then from the synchronous design of the FPGA state machines. The exposure time $t_{exposure}$ is controlled with an internal exposure time controller.

The trigger pulse from the internal camera module control starts also the strobe control state machines. The strobe can be delayed by $t_{strobe-delay}$ with an internal counter which can be controlled by the customer via software settings. The strobe offset delay $t_{strobe-delay}$ results then from the synchronous design of the FPGA state machines. A second counter determines the strobe duration $t_{strobe-duration}$(strobe-duration). For a robust system design the strobe output is also isolated from the camera module electronic which leads to an additional delay of $t_{d-iso-output}$. Table 4.8, Table 4.9 and Table 4.10 gives an overview over the minimum and maximum values of the parameters.

External Trigger with Pulsewidth controlled Exposure Time

In the external trigger mode with Pulsewidth controlled exposure time the rising edge of the trigger pulse starts the camera module states machine, which controls the sensor. The falling edge of the trigger pulse stops the image acquisition. Additionally the optional external strobe output is controlled by the rising edge of the trigger pulse. Timing diagram Fig. 4.32 shows the detailed timing for the external trigger mode with pulse width controlled exposure time.

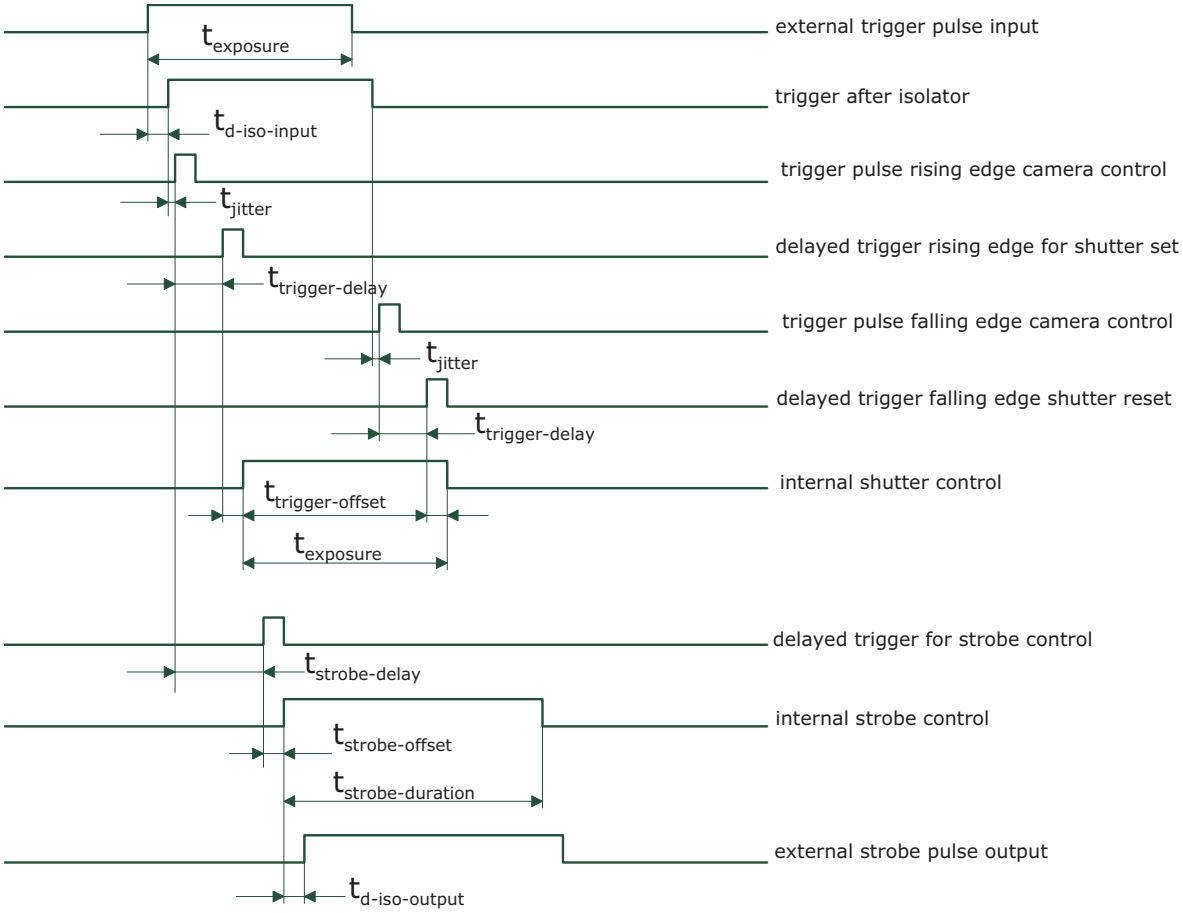


Figure 4.32: Timing diagram for the Pulsewidth controlled exposure time

The timing of the rising edge of the trigger pulse until to the start of exposure and strobe is equal to the timing of the camera module controlled exposure time (see Section 4.4.3). In this mode however the end of the exposure is controlled by the falling edge of the trigger Pulsewidth:
The falling edge of the trigger pulse is delayed by the time $t_{d-iso-input}$ which is results from the signal isolator. This signal is clocked into the FPGA which leads to a jitter of t_{jitter}. The pulse is then delayed by $t_{trigger-delay}$ by the user defined value which can be configured via camera module software. After the trigger offset time $t_{trigger-offset}$ the exposure is stopped.

4.4.4 Trigger Delay

The trigger delay is a programmable delay in milliseconds between the incoming trigger edge and the start of the exposure. This feature may be required to synchronize to external strobe with the exposure of the camera module.

4.4.5 Burst Trigger

The camera module includes a burst trigger engine. When enabled, it starts a predefined number of acquisitions after one single trigger pulse. The time between two acquisitions and the number of acquisitions can be configured by a user defined value via the camera module software. The burst trigger feature works only in the mode "Camera controlled Exposure Time".

The burst trigger signal can be configured to be active high or active low. When the frequency of the incoming burst triggers is higher than the duration of the programmed burst sequence, then some trigger pulses will be missed. A missed burst trigger counter counts these events. This counter can be read out by the user.

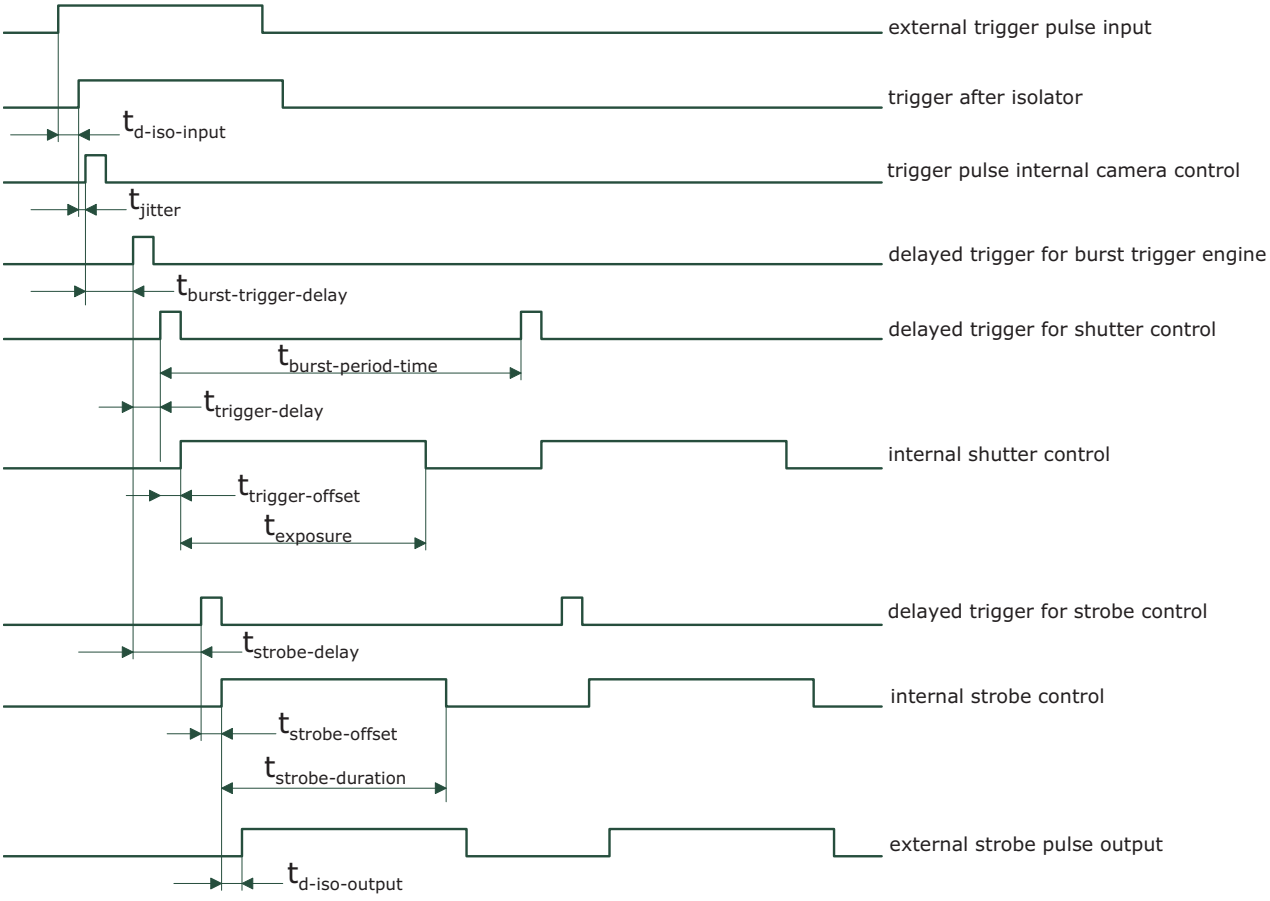


Figure 4.33: Timing diagram for the burst trigger mode

The timing diagram of the burst trigger mode is shown in Fig. 4.33. The timing of the "external trigger pulse input" until to the "trigger pulse internal camera control" is equal to the timing in the section Fig. 4.32. This trigger pulse then starts after a user configurable burst trigger delay time $t_{burst-trigger-delay}$ the internal burst engine, which generates n internal triggers for the shutter- and the strobe-control. A user configurable value defines the time $t_{burst-period-time}$ between two acquisitions.

	OEM-D1312(I)-40	OEM-D1312(I)-40
Timing Parameter	**Minimum**	**Maximum**
$t_{d-iso-input}$	45 ns	60 ns
t_{jitter}	0	100 ns
$t_{trigger-delay}$	0	1.68 s
$t_{burst-trigger-delay}$	0	1.68 s
$t_{burst-period-time}$	depends on camera module settings	1.68 s
$t_{trigger-offset}$ (non burst mode)	400 ns	400 ns
$t_{trigger-offset}$ (burst mode)	500 ns	500 ns
$t_{exposure}$	10 μs	1.68 s
$t_{strobe-delay}$	0	1.68 s
$t_{strobe-offset}$ (non burst mode)	400 ns	400 ns
$t_{strobe-offset}$ (burst mode)	500 ns	500 ns
$t_{strobe-duration}$	200 ns	1.68 s
$t_{d-iso-output}$	45 ns	60 ns
$t_{trigger-pulsewidth}$	200 ns	n/a
Number of bursts n	1	30000

Table 4.8: Summary of timing parameters relevant in the external trigger mode using camera module (OEM-D1312(I)-40)

4.4.6 Software Trigger

The software trigger enables to emulate an external trigger pulse by the camera module software through the serial data interface. It works with both burst mode enabled and disabled. As soon as it is performed via the camera module software, it will start the image acquisition(s), depending on the usage of the burst mode and the burst configuration. The trigger mode must be set to `Interface Trigger` or `I/O Trigger`.

4.4.7 Strobe Output

The strobe outpu can be used to trigger a strobe. The strobe output can be used both in free-running and in trigger mode. There is a programmable delay available to adjust the strobe pulse to your application.

	OEM-D1312(I)-80	OEM-D1312(I)-80
Timing Parameter	**Minimum**	**Maximum**
$t_{d-iso-input}$	45 ns	60 ns
t_{jitter}	0	50 ns
$t_{trigger-delay}$	0	0.84 s
$t_{burst-trigger-delay}$	0	0.84 s
$t_{burst-period-time}$	depends on camera module settings	0.84 s
$t_{trigger-offset}$ (non burst mode)	200 ns	200 ns
$t_{trigger-offset}$ (burst mode)	250 ns	250 ns
$t_{exposure}$	10 μs	0.84 s
$t_{strobe-delay}$	600 ns	0.84 s
$t_{strobe-offset}$ (non burst mode)	200 ns	200 ns
$t_{strobe-offset}$ (burst mode)	250 ns	250 ns
$t_{strobe-duration}$	200 ns	0.84 s
$t_{d-iso-output}$	45 ns	60 ns
$t_{trigger-pulsewidth}$	200 ns	n/a
Number of bursts n	1	30000

Table 4.9: Summary of timing parameters relevant in the external trigger mode using camera module (OEM-D1312(I)-80)

	OEM-D1312(I)-160	OEM-D1312(I)-160
Timing Parameter	**Minimum**	**Maximum**
$t_{d-iso-input}$	45 ns	60 ns
t_{jitter}	0	25 ns
$t_{trigger-delay}$	0	0.42 s
$t_{burst-trigger-delay}$	0	0.42 s
$t_{burst-period-time}$	depends on camera module settings	0.42 s
$t_{trigger-offset}$ (non burst mode)	100 ns	100 ns
$t_{trigger-offset}$ (burst mode)	125 ns	125 ns
$t_{exposure}$	10 μs	0.42 s
$t_{strobe-delay}$	0	0.42 s
$t_{strobe-offset}$ (non burst mode)	100 ns	100 ns
$t_{strobe-offset}$ (burst mode)	125 ns	125 ns
$t_{strobe-duration}$	200 ns	0.42 s
$t_{d-iso-output}$	45 ns	60 ns
$t_{trigger-pulsewidth}$	200 ns	n/a
Number of bursts n	1	30000

Table 4.10: Summary of timing parameters relevant in the external trigger mode using camera module (OEM-D1312(I)-160)

4.5 Data Path Overview

The data path is the path of the image from the output of the image sensor to the output of the camera module. The sequence of blocks is shown in figure Fig. 4.34.

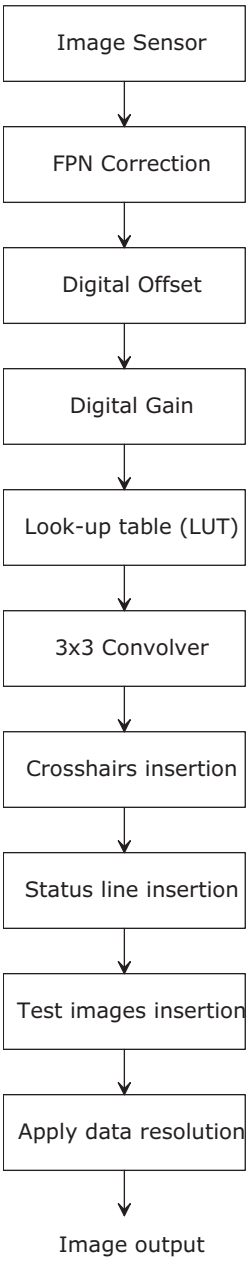


Figure 4.34: camera module data path

4.6 Image Correction

4.6.1 Overview

The camera module possesses image pre-processing features, that compensate for non-uniformities caused by the sensor, the lens or the illumination. This method of improving the image quality is generally known as 'Shading Correction' or 'Flat Field Correction' and consists of a combination of offset correction, gain correction and pixel interpolation.

Since the correction is performed in hardware, there is no performance limitation of the camera modules for high frame rates.

The offset correction subtracts a configurable positive or negative value from the live image and thus reduces the fixed pattern noise of the CMOS sensor. In addition, hot pixels can be removed by interpolation. The gain correction can be used to flatten uneven illumination or to compensate shading effects of a lens. Both offset and gain correction work on a pixel-per-pixel basis, i.e. every pixel is corrected separately. For the correction, a black reference and a grey reference image are required. Then, the correction values are determined automatically in the camera module.

Do not set any reference images when gain or LUT is enabled! Read the following sections very carefully.

Correction values of both reference images can be saved into the internal flash memory, but this overwrites the factory presets. Then the reference images that are delivered by factory cannot be restored anymore.

4.6.2 Offset Correction (FPN, Hot Pixels)

The offset correction is based on a black reference image, which is taken at no illumination (e.g. lens aperture completely closed). The black reference image contains the fixed-pattern noise of the sensor, which can be subtracted from the live images in order to minimise the static noise.

Offset correction algorithm

After configuring the camera module with a black reference image, the camera module is ready to apply the offset correction:

1. Determine the average value of the black reference image.
2. Subtract the black reference image from the average value.
3. Mark pixels that have a grey level higher than 1008 DN (@ 12 bit) as hot pixels.
4. Store the result in the camera module as the offset correction matrix.
5. During image acquisition, subtract the correction matrix from the acquired image and interpolate the hot pixels (see Section 4.6.2).

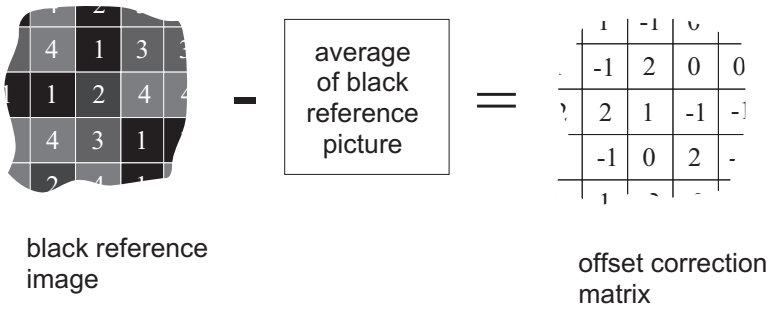


Figure 4.35: Schematic presentation of the offset correction algorithm

How to Obtain a Black Reference Image

In order to improve the image quality, the black reference image must meet certain demands.

- The black reference image must be obtained at no illumination, e.g. with lens aperture closed or closed lens opening.
- It may be necessary to adjust the black level offset of the camera module. In the histogram of the black reference image, ideally there are no grey levels at value 0 DN after adjustment of the black level offset. All pixels that are saturated black (0 DN) will not be properly corrected (see Fig. 4.36). The peak in the histogram should be well below the hot pixel threshold of 1008 DN @ 12 bit.
- camera module settings may influence the grey level. Therefore, for best results the camera module settings of the black reference image must be identical with the camera module settings of the image to be corrected.

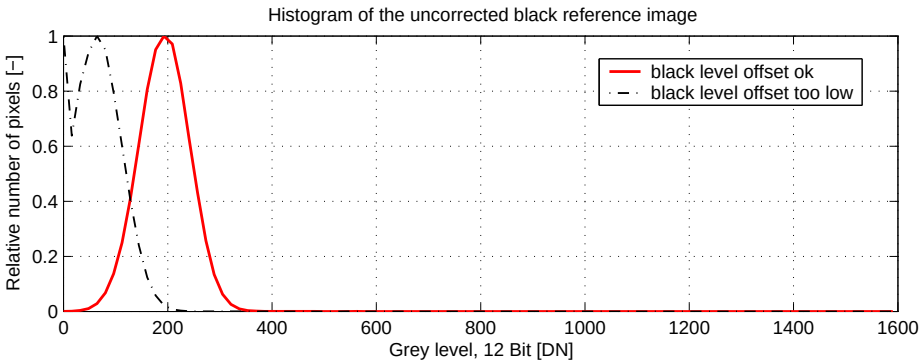


Figure 4.36: Histogram of a proper black reference image for offset correction

Hot pixel correction

Every pixel that exceeds a certain threshold in the black reference image is marked as a hot pixel. If the hot pixel correction is switched on, the camera module replaces the value of a hot pixel by an average of its neighbour pixels (see Fig. 4.37).

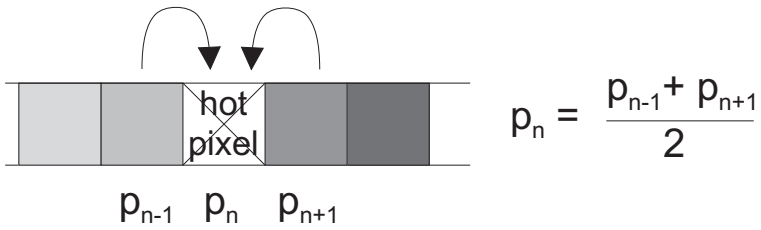


Figure 4.37: Hot pixel interpolation

4.6.3 Gain Correction

The gain correction is based on a grey reference image, which is taken at uniform illumination to give an image with a mid grey level.

Gain correction is not a trivial feature. The quality of the grey reference image is crucial for proper gain correction.

Gain correction algorithm

After configuring the camera module with a black and grey reference image, the camera module is ready to apply the gain correction:

1. Determine the average value of the grey reference image.
2. Subtract the offset correction matrix from the grey reference image.
3. Divide the average value by the offset corrected grey reference image.
4. Pixels that have a grey level higher than a certain threshold are marked as hot pixels.
5. Store the result in the camera module as the gain correction matrix.
6. During image acquisition, multiply the gain correction matrix from the offset-corrected acquired image and interpolate the hot pixels (see Section 4.6.2).

Gain correction is not a trivial feature. The quality of the grey reference image is crucial for proper gain correction.

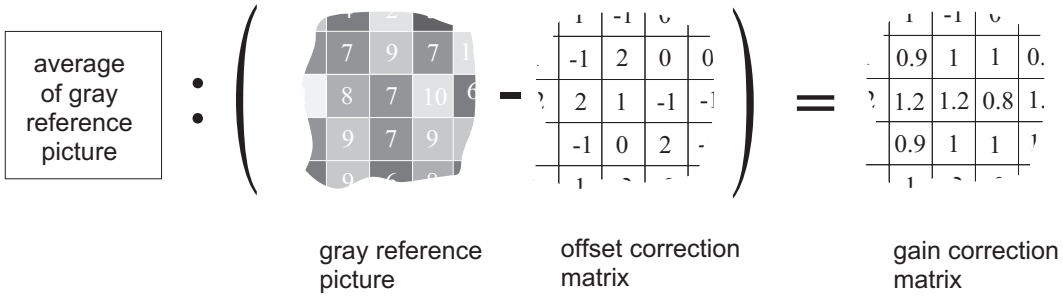


Figure 4.38: Schematic presentation of the gain correction algorithm

Gain correction always needs an offset correction matrix. Thus, the offset correction always has to be performed before the gain correction.

How to Obtain a Grey Reference Image

In order to improve the image quality, the grey reference image must meet certain demands.

- The grey reference image must be obtained at uniform illumination.

  Use a high quality light source that delivers uniform illumination. Standard illumination will not be appropriate.

- When looking at the histogram of the grey reference image, ideally there are no grey levels at full scale (4095 DN @ 12 bit). All pixels that are saturated white will not be properly corrected (see Fig. 4.39).
- camera module settings may influence the grey level. Therefore, the camera module settings of the grey reference image must be identical with the camera module settings of the image to be corrected.

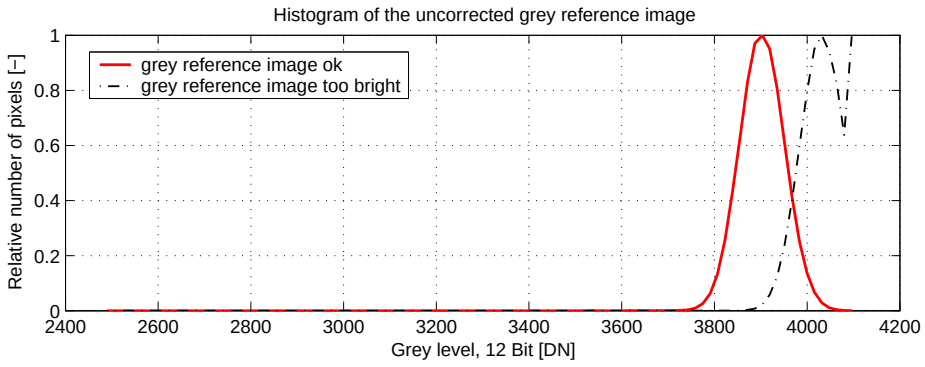


Figure 4.39: Proper grey reference image for gain correction

4.6.4 Corrected Image

Offset, gain and hot pixel correction can be switched on separately. The following configurations are possible:

- No correction
- Offset correction only
- Offset and hot pixel correction
- Hot pixel correction only
- Offset and gain correction
- Offset, gain and hot pixel correction

In addition, the black reference image and grey reference image that are currently stored in the camera module RAM can be output.

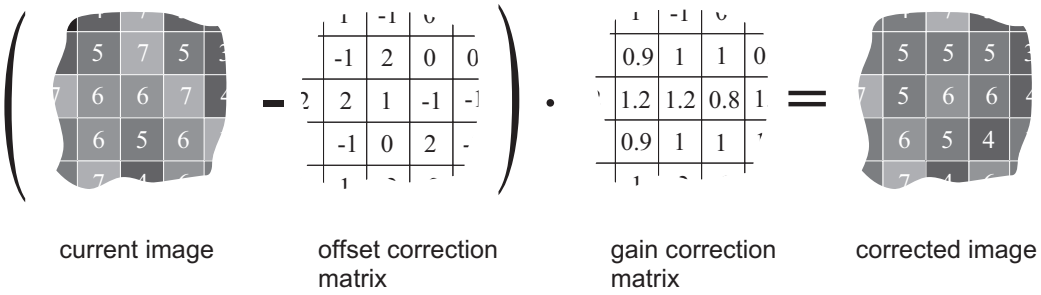


Figure 4.40: Schematic presentation of the corrected image using gain correction algorithm

Table 4.11 shows the minimum and maximum values of the correction matrices, i.e. the range that the offset and gain algorithm can correct.

	Minimum	Maximum
Offset correction	-1023 DN @ 12 bit	+1023 DN @ 12 bit
Gain correction	0.42	2.67

Table 4.11: Offset and gain correction ranges

4.7 Digital Gain and Offset

Gain x1, x2, x4 and x8 are digital amplifications, which means that the digital image data are multiplied in the camera module by a factor 1, 2, 4 or 8, respectively. It is implemented as a binary shift of the image data, which means that there will be missing codes in the output image as the LSB's of the gray values are set to '0'. E.g. for gain x2, the output value is shifted by 1 and bit 0 is set to '0'.
A user-defined value can be subtracted from the gray value in the digital offset block. This feature is not available in Gain x1 mode. If digital gain is applied and if the brightness of the image is too big then the output image might be saturated. By subtracting an offset from the input of the gain block it is possible to avoid the saturation.

4.8 Grey Level Transformation (LUT)

Grey level transformation is remapping of the grey level values of an input image to new values. The look-up table (LUT) is used to convert the greyscale value of each pixel in an image into another grey value. It is typically used to implement a transfer curve for contrast expansion. The camera module performs a 12-to-8-bit mapping, so that 4096 input grey levels can be mapped to 256 output grey levels. The use of the three available modes is explained in the next sections. Two LUT and a Region-LUT feature are available in the OEM-D1312 camera module series (see Section 4.8.4).

The output grey level resolution of the look-up table (independent of gain, gamma or user-definded mode) is always 8 bit.

There are 2 predefined functions, which generate a look-up table and transfer it to the camera module. For other transfer functions the user can define his own LUT file.

Some commonly used transfer curves are shown in Fig. 4.41. Line a denotes a negative or inverse transformation, line b enhances the image contrast between grey values x0 and x1. Line c shows brightness thresholding and the result is an image with only black and white grey levels. and line d applies a gamma correction (see also Section 4.8.2).

4.8.1 Gain

The 'Gain' mode performs a digital, linear amplification with clamping (see Fig. 4.42). It is configurable in the range from 1.0 to 4.0 (e.g. 1.234).

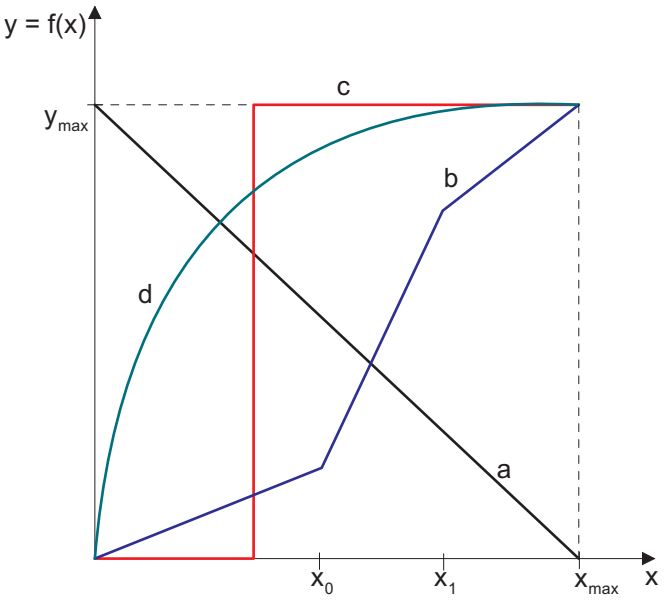


Figure 4.41: Commonly used LUT transfer curves

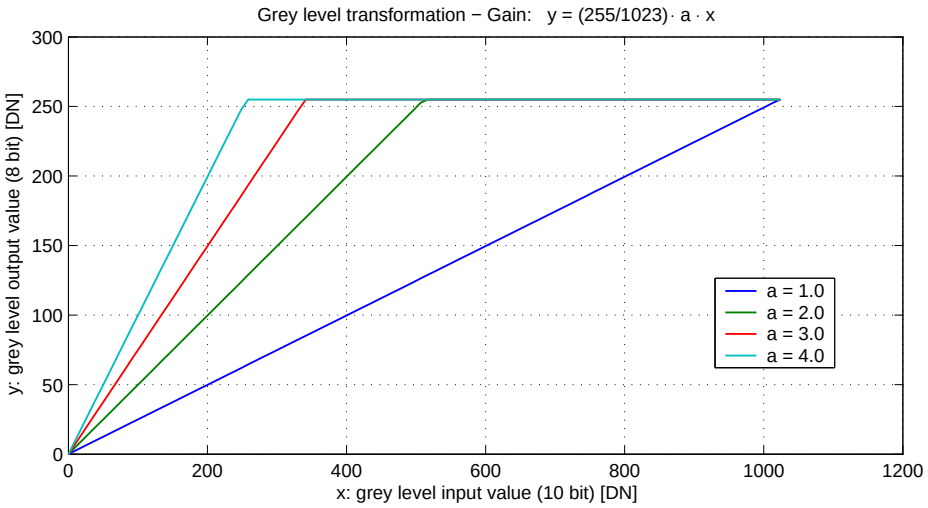


Figure 4.42: Applying a linear gain with clamping to an image

4.8.2 Gamma

The 'Gamma' mode performs an exponential amplification, configurable in the range from 0.4 to 4.0. Gamma > 1.0 results in an attenuation of the image (see Fig. 4.43), gamma < 1.0 results in an amplification (see Fig. 4.44). Gamma correction is often used for tone mapping and better display of results on monitor screens.

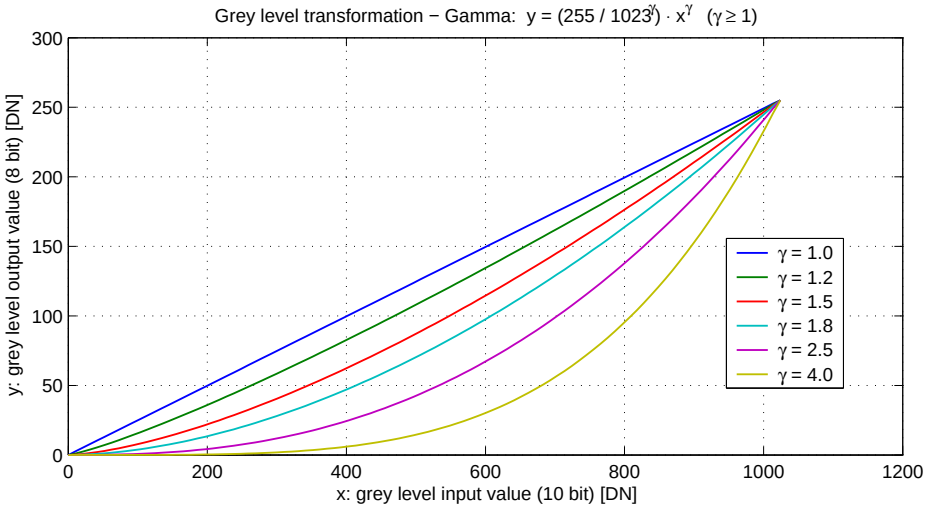


Figure 4.43: Applying gamma correction to an image (gamma > 1)

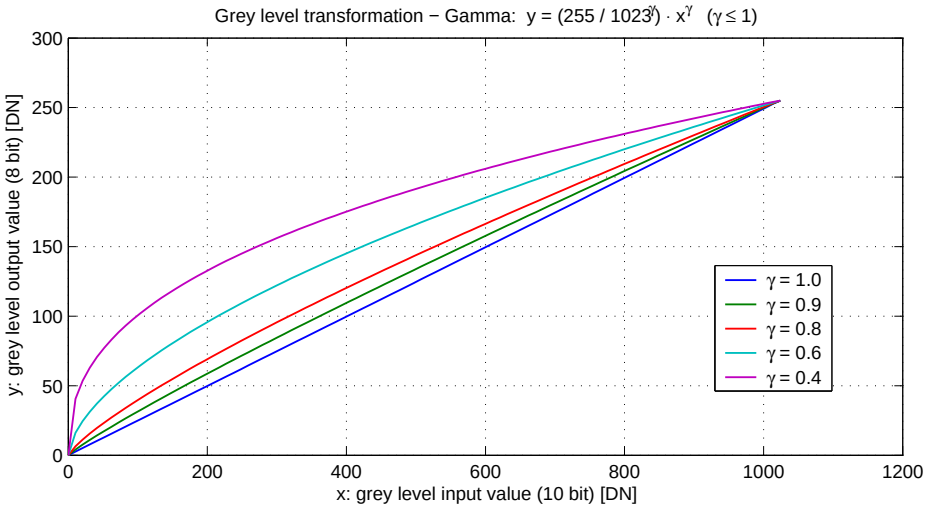


Figure 4.44: Applying gamma correction to an image (gamma < 1)

4.8.3 User-defined Look-up Table

In the 'User' mode, the mapping of input to output grey levels can be configured arbitrarily by the user. There is an example file in the PFRemote folder. LUT files can easily be generated with a standard spreadsheet tool. The file has to be stored as tab delimited text file.

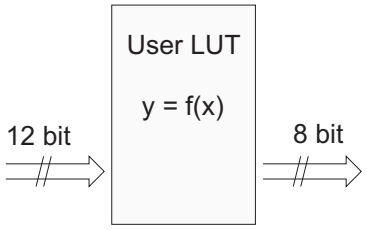


Figure 4.45: Data path through LUT

4.8.4 Region LUT and LUT Enable

Two LUT's and a Region-LUT feature are available in the OEM-D1312(I) camera module series. Both LUT's can be enabled independently (see 4.12). LUT 0 supersedes LUT1.
When Region-LUT feature is enabled, then the LUT's are only active in a user defined region. Examples are shown in Fig. 4.46 and Fig. 4.47.
Fig. 4.46 shows an example of overlapping Region-LUT's. LUT 0, LUT 1 and Region LUT are enabled. LUT 0 is active in region 0 ((x00, x01), (y00, y01)) and it supersedes LUT 1 in the overlapping region. LUT 1 is active in region 1 ((x10, x11), (y10, y11)).
Fig. 4.47 shows an example of keyhole inspection in a laser welding application. LUT 0 and LUT 1 are used to enhance the contrast by applying optimized transfer curves to the individual regions. LUT 0 is used for keyhole inspection. LUT 1 is optimized for seam finding.
Fig. 4.48 shows the application of the Region-LUT to a image. The original image without image processing is shown on the left-hand side. The result of the application of the Region-LUT is shown on the right-hand side. One Region-LUT was applied on a small region on the lower part of the image where the brightness has been increased.

Enable LUT 0	Enable LUT 1	Enable Region LUT	Description
-	-	-	LUT are disabled.
X	don't care	-	LUT 0 is active on whole image.
-	X	-	LUT 1 is active on whole image.
X	-	X	LUT 0 active in Region 0.
X	X	X	LUT 0 active in Region 0 and LUT 1 active
			in Region 1. LUT 0 supersedes LUT1.

Table 4.12: LUT Enable and Region LUT

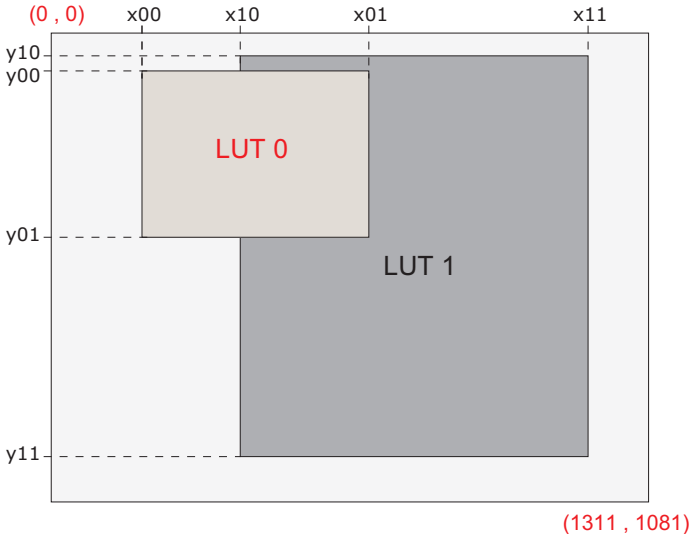


Figure 4.46: Overlapping Region-LUT example

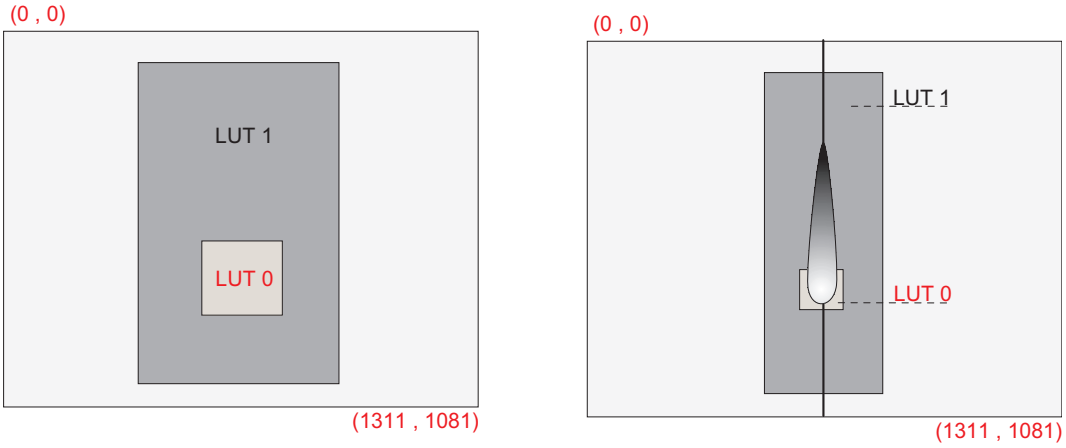


Figure 4.47: Region-LUT in keyhole inspection

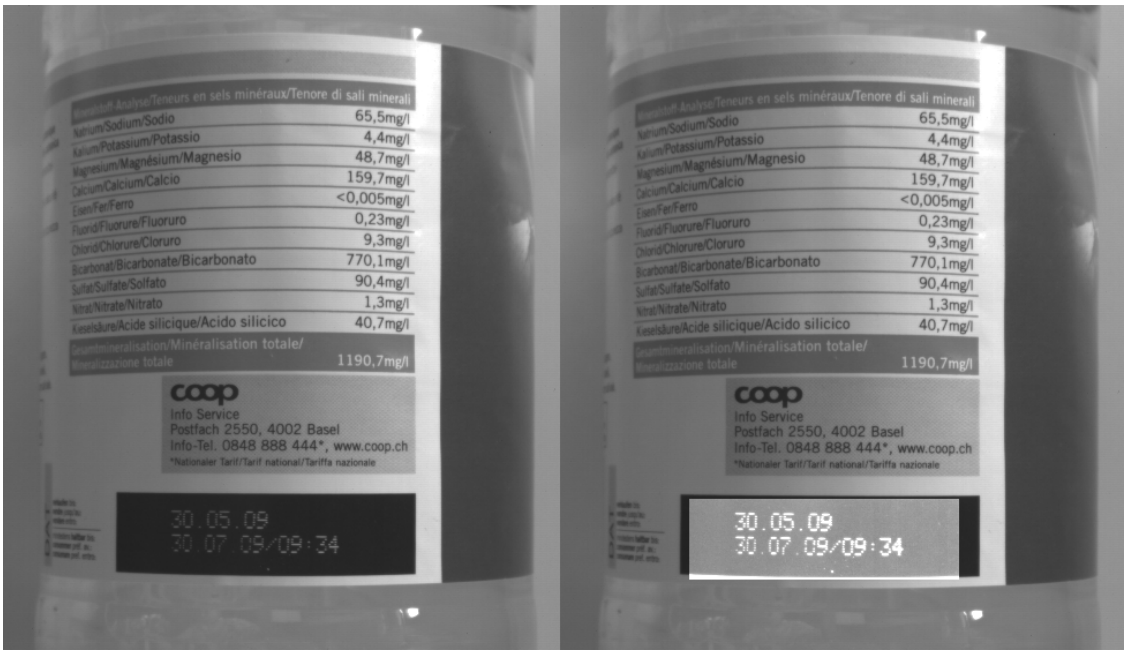


Figure 4.48: Region-LUT example with camera image; left: original image; right: gain 4 region in the are of the date print of the bottle

4.9 Convolver

4.9.1 Functionality

The "Convolver" is a discrete 2D-convolution filter with a 3x3 convolution kernel. The kernel coefficients can be user-defined.
The M x N discrete 2D-convolution $p_{out}(x,y)$ of pixel $p_{in}(x,y)$ with convolution kernel h, scale s and offset o is defined in Fig. 4.49.

$$p_{\mathrm{out}}(x,y)=\frac{1}{s}\left(\sum_{m^*=0}^{M-1}\sum_{n^*=0}^{N-1} h(m^*,n^*)\; p_{\mathrm{in}}\left(x-\frac{M-1}{2}+m^*,\; y-\frac{N-1}{2}+n^*\right)\right)+o$$

Figure 4.49: Convolution formula

4.9.2 Settings

The following settings for the parameters are available:

Offset Offset value o (see Fig. 4.49). Range: -4096 ... 4095

Scale Scaling divisor s (see Fig. 4.49). Range: 1 ... 4095

Coefficients Coefficients of convolution kernel h (see Fig. 4.49). Range: -4096 ... 4095. Assignment to coefficient properties is shown in Fig. 4.50.

$$\begin{bmatrix} Coeff0 & Coeff1 & Coeff2 \\ Coeff3 & Coeff4 & Coeff5 \\ Coeff6 & Coeff7 & Coeff8 \end{bmatrix}$$

Figure 4.50: Convolution coefficients assignment

4.9.3 Examples

Fig. 4.51 shows the result of the application of various standard convolver settings to the original image. shows the corresponding settings for every filter.
A filter called `Unsharp Mask` is often used to enhance near infrared images. Fig. 4.53 shows examples with the corresponding settings.

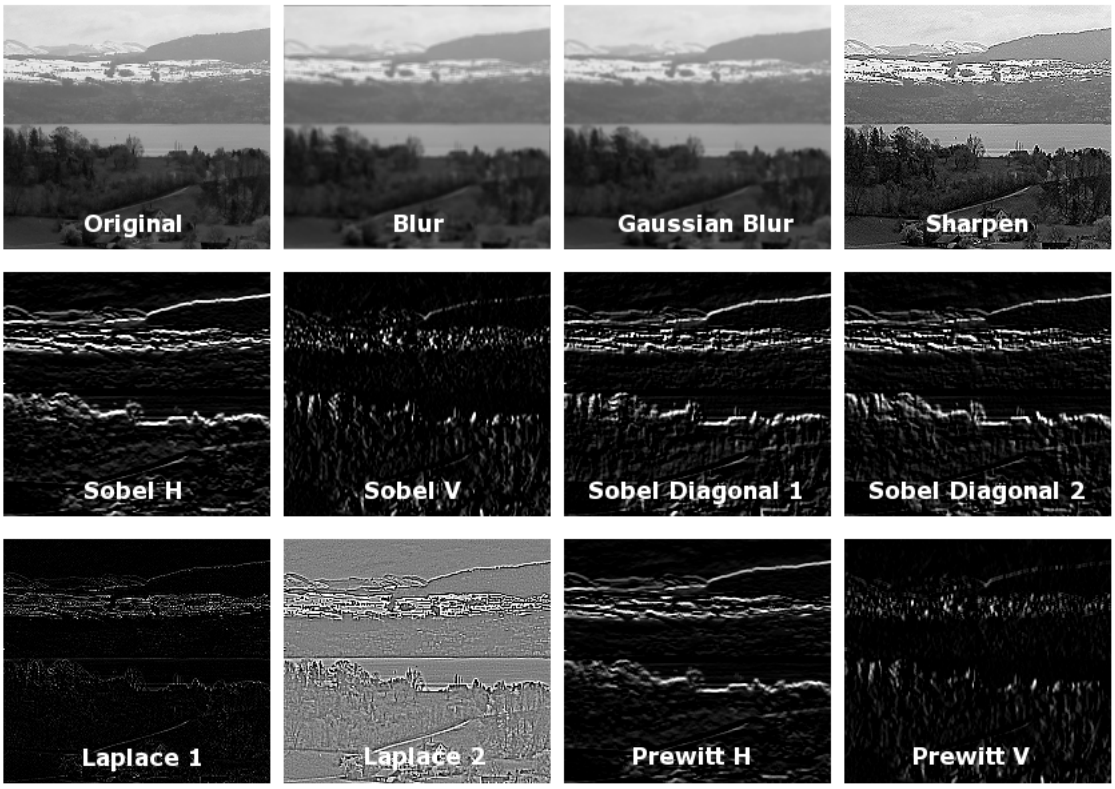
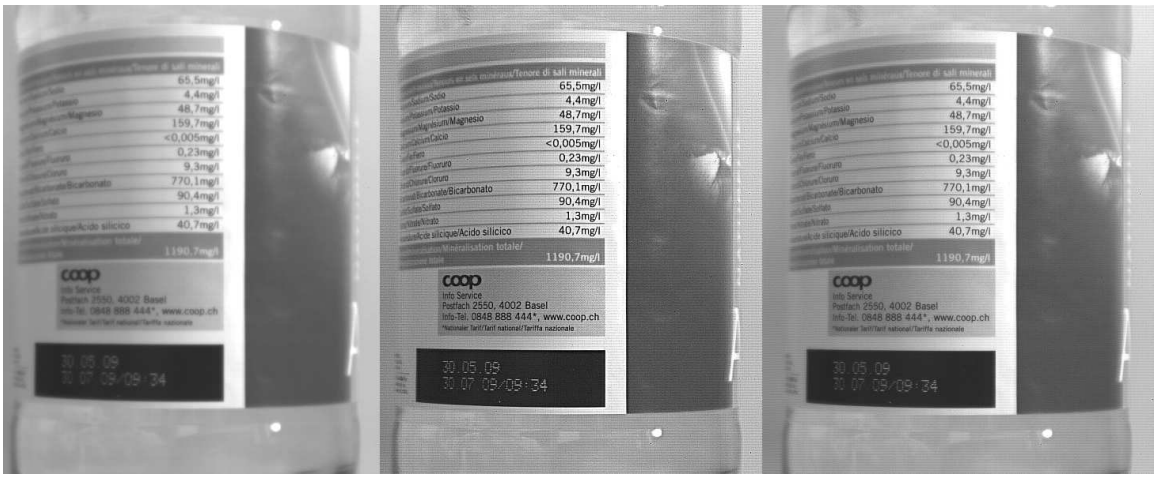


Figure 4.51: 3x3 Convolution filter examples 1

Original Offset = 0 Scale = 1 $\begin{bmatrix} 0 & 0 & 0 \\ 0 & 1 & 0 \\ 0 & 0 & 0 \end{bmatrix}$	**Blur** Offset = 0 Scale = 9 $\begin{bmatrix} 1 & 1 & 1 \\ 1 & 1 & 1 \\ 1 & 1 & 1 \end{bmatrix}$	**Gaussian Blur** Offset = 0 Scale = 16 $\begin{bmatrix} 1 & 2 & 1 \\ 2 & 4 & 2 \\ 1 & 2 & 1 \end{bmatrix}$	**Sharpen** Offset = 0 Scale = 1 $\begin{bmatrix} 0 & -1 & 0 \\ -1 & 5 & -1 \\ 0 & -1 & 0 \end{bmatrix}$
Sobel H Offset = 0 Scale = 1 $\begin{bmatrix} 1 & 2 & 1 \\ 0 & 0 & 0 \\ -1 & -2 & -1 \end{bmatrix}$	**Sobel V** Offset = 0 Scale = 1 $\begin{bmatrix} 1 & 0 & -1 \\ 2 & 0 & -2 \\ 1 & 0 & -1 \end{bmatrix}$	**Sobel Diagonal 1** Offset = 0 Scale = 1 $\begin{bmatrix} 2 & 1 & 0 \\ 1 & 0 & -1 \\ 0 & -1 & -2 \end{bmatrix}$	**Sobel Diagonal 2** Offset = 0 Scale = 1 $\begin{bmatrix} 0 & 1 & 2 \\ -1 & 0 & 1 \\ -2 & -1 & 0 \end{bmatrix}$
Laplace 1 Offset = 0 Scale = 1 $\begin{bmatrix} 0 & -1 & 0 \\ -1 & 4 & -1 \\ 0 & -1 & 0 \end{bmatrix}$	**Laplace 2** Offset = 128 Scale = 1 $\begin{bmatrix} -1 & -1 & -1 \\ -1 & 8 & -1 \\ -1 & -1 & -1 \end{bmatrix}$	**Prewitt H** Offset = 0 Scale = 1 $\begin{bmatrix} 1 & 1 & 1 \\ 0 & 0 & 0 \\ -1 & -1 & -1 \end{bmatrix}$	**Prewitt V** Offset = 0 Scale = 1 $\begin{bmatrix} 1 & 0 & -1 \\ 1 & 0 & -1 \\ 1 & 0 & -1 \end{bmatrix}$

Figure 4.52: 3x3 Convolution filter examples 1 settings



Original image

Unsharp mask
Offset = 0
Scale = 1

$$\begin{bmatrix} -1 & -1 & -1 \\ -1 & 9 & -1 \\ -1 & -1 & -1 \end{bmatrix}$$

Unsharp mask with Gaussian
Offset = 0
Scale = 6

$$\begin{bmatrix} -1 & -4 & -1 \\ -4 & 26 & -4 \\ -1 & -4 & -1 \end{bmatrix}$$

Figure 4.53: Unsharp Mask Examples

4.10 Crosshairs

4.10.1 Functionality

The crosshairs inserts a vertical and horizontal line into the image. The width of these lines is one pixel. The grey level is defined by a 12 bit value (0 means black, 4095 means white). This allows to set any grey level to get the maximum contrast depending on the acquired image. The x/y position and the grey level can be set via the camera module software. Figure Fig. 4.54 shows two examples of the activated crosshairs with different grey values. One with white lines and the other with black lines.

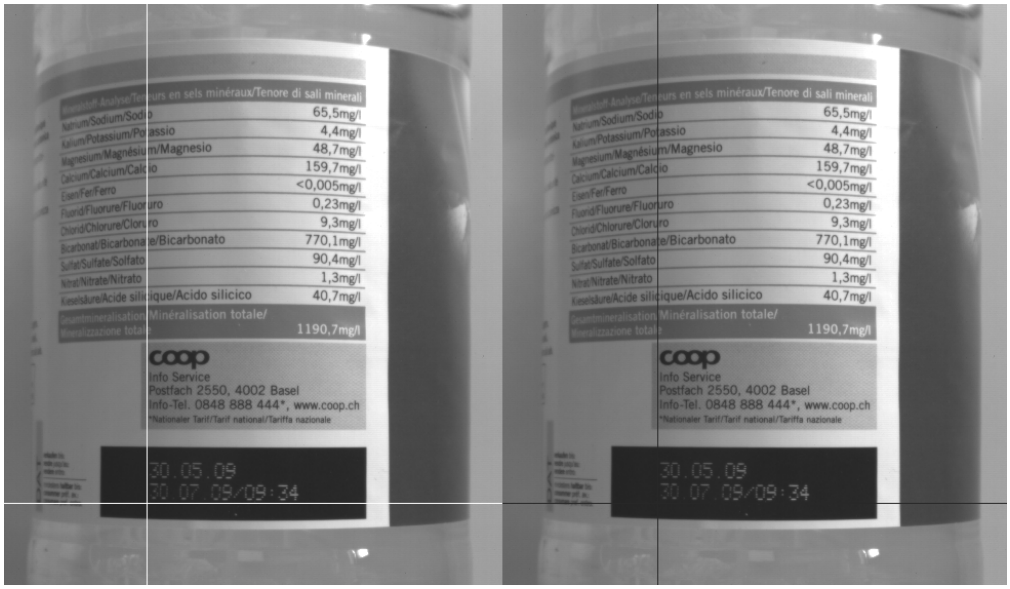


Figure 4.54: Crosshairs Example with different grey values

The x- and y-positon is absolute to the sensor pixel matrix. It is independent on the ROI, MROI or decimation configurations. Figure Fig. 4.55 shows two situations of the crosshairs configuration. The same MROI settings is used in both situations. The crosshairs however is set differently. The crosshairs is not seen in the image on the right, because the x- and y-position is set outside the MROI region.

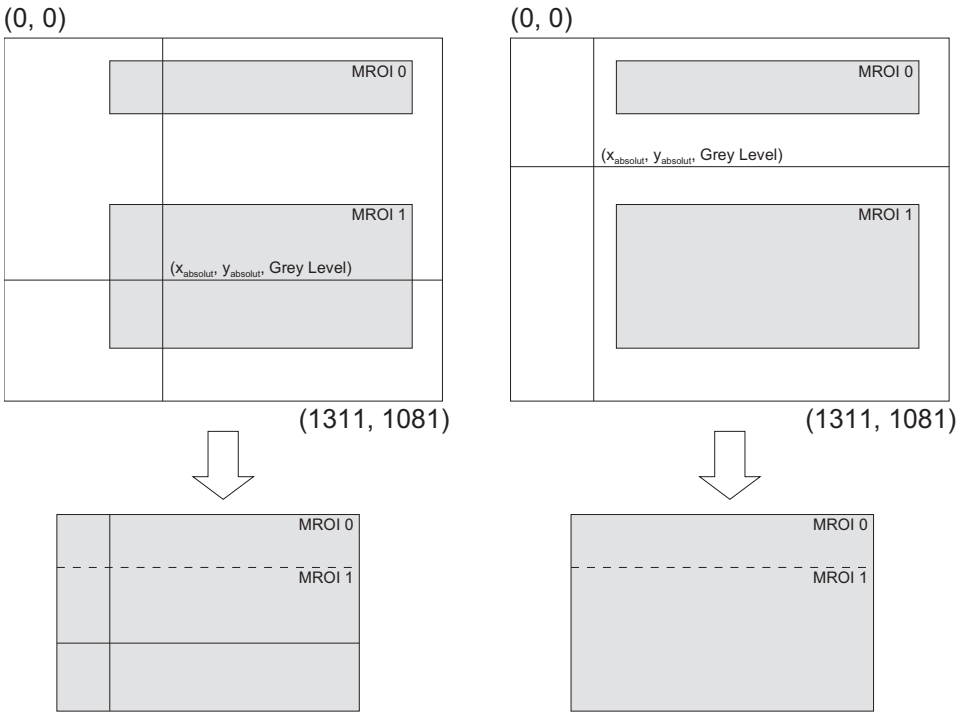


Figure 4.55: Crosshairs absolute position

4.11 Image Information and Status Line

There are camera module properties available that give information about the acquired images, such as an image counter, average image value and the number of missed trigger signals. These properties can be queried by software. Alternatively, a status line within the image data can be switched on that contains all the available image information.

4.11.1 Counters and Average Value

Image counter The image counter provides a sequential number of every image that is output. After camera module startup, the counter counts up from 0 (counter width 24 bit). The counter can be reset by the camera module control software.

Real Time counter The time counter starts at 0 after camera module start, and counts real-time in units of 1 micro-second. The time counter can be reset by the software in the SDK (Counter width 32 bit).

Missed trigger counter The missed trigger counter counts trigger pulses that were ignored by the camera module because they occurred within the exposure or read-out time of an image. In free-running mode it counts all incoming external triggers (counter width 8 bit / no wrap around).

Missed burst trigger counter The missed burst trigger counter counts trigger pulses that were ignored by the camera module in the burst trigger mode because they occurred while the camera module still was processing the current burst trigger sequence.

Average image value The average image value gives the average of an image in 12 bit format (0 .. 4095 DN), regardless of the currently used grey level resolution.

4.11.2 Status Line

If enabled, the status line replaces the last row of the image with camera module status information. Every parameter is coded into fields of 4 pixels (LSB first) and uses the lower 8 bits of the pixel value, so that the total size of a parameter field is 32 bit (see Fig. 4.56). The assignment of the parameters to the fields is listed in 4.13.

The status line is available in all camera module modes.

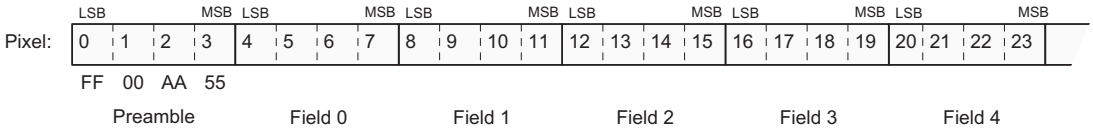


Figure 4.56: Status line parameters replace the last row of the image

Start pixel index	Parameter width [bit]	Parameter Description
0	32	Preamble: 0x55AA00FF
4	24	Image Counter (see Section 4.11.1)
8	32	Real Time Counter (see Section 4.11.1)
12	8	Missed Trigger Counter (see Section 4.11.1)
16	12	Image Average Value (see Section 4.11.1)
20	24	Integration Time in units of clock cycles (see Table 3.3)
24	16	Burst Trigger Number
28	8	Missed Burst Trigger Counter
32	11	Horizontal start position of ROI (Window.X)
36	11	Horizontal end position of ROI
		(= Window.X + Window.W - 1)
40	11	Vertical start position of ROI (Window.Y).
		In MROI-mode this parameter is 0.
44	11	Vertical end position of ROI (Window.Y + Window.H - 1).
		In MROI-mode this parameter is the total height - 1.
48	2	Trigger Source
52	2	Digital Gain
56	2	Digital Offset
60	16	camera module Type Code (see 4.14)
64	32	camera module Serial Number

Table 4.13: Assignment of status line fields

Camera module Model	Camera module Type Code
OEM-D1312-40-CL-12	210
OEM-D1312-80-CL-12	211
OEM-D1312-160-CL-12	212
OEM-D1312I-40-CL-12	230
OEM-D1312I-80-CL-12	231
OEM-D1312I-160-CL-12	232

Table 4.14: Type codes of OEM-D1312 cameras

4.12 Test Images

TTest images are generated in the camera module FPGA, independent of the image sensor. They can be used to check the transmission path from the camera module to the user electronic. Independent from the configured grey level resolution, every possible grey level appears the same number of times in a test image. Therefore, the histogram of the received image must be flat.

A test image is a useful tool to find data transmission errors that are caused most often by a defective interface.

The analysis of the test images with a histogram tool gives the correct result at a resolution of 1024 x 1024 pixels only.

4.12.1 Ramp

Depending on the configured grey level resolution, the ramp test image outputs a constant pattern with increasing grey level from the left to the right side (see Fig. 4.57).

Figure 4.57: Ramp test images: 8 bit output (left), 10 bit output (middle),12 (right)

4.12.2 LFSR

The LFSR (linear feedback shift register) test image outputs a constant pattern with a pseudo-random grey level sequence containing every possible grey level that is repeated for every row. The LFSR test pattern was chosen because it leads to a very high data toggling rate, which stresses the interface electronic and the cable connection.

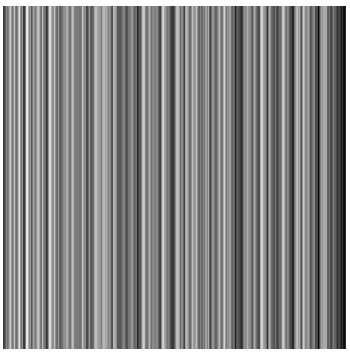


Figure 4.58: LFSR (linear feedback shift register) test image

In the histogram you can see that the number of pixels of all grey values are the same. Please refer to application note [AN026] for the calculation and the values of the LFSR test image.

4.12.3 Troubleshooting using the LFSR

To control the quality of your complete imaging system enable the LFSR mode, set the camera window to 1024 x 1024 pixels (x=0 and y=0) and check the histogram. If your frame grabber application does not provide a real-time histogram, store the image and use a graphic software tool to display the histogram.
n the LFSR (linear feedback shift register) mode the camera module generates a constant test pattern containing all grey levels. If the data transmission is error free, the histogram of the received LFSR test pattern will be flat (Fig. 4.59). On the other hand, a non-flat histogram (Fig. 4.60) indicates problems, that may be caused by the interface.

Figure 4.59: LLFSR test pattern and typical histogram for error-free data transmission

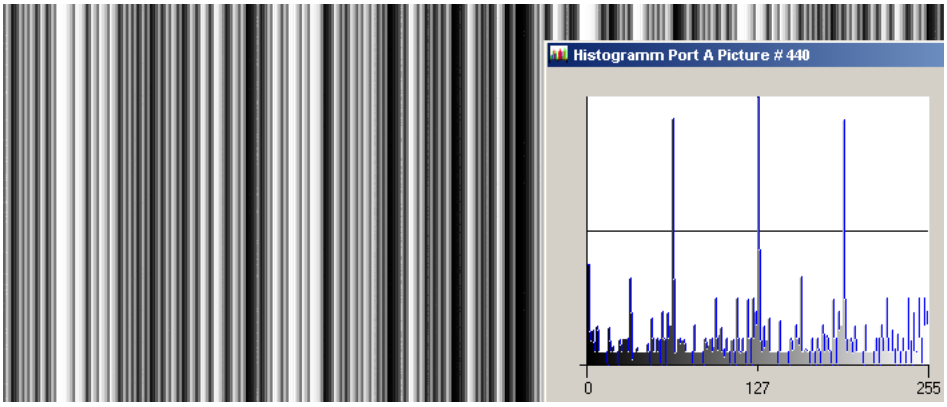


Figure 4.60: LFSR test pattern and histogram containing data transmission errors

The LFSR test works only for an image width of 1024, otherwise the histogram will not be flat.

5 Hardware Interface

5.1 Connectors

5.1.1 Power Supply

The OEM camera modules require three power supply voltages. The OEM camera modules meet all performance specifications using standard switching power supplies, although well-regulated linear power supplies provide optimum performance.

It is extremely important that you apply the appropriate voltages to your OEM camera module. Incorrect voltages will damage the OEM camera modules.

Table 5.1 summarizes the specifications for the power supply voltages and Table 5.2 summarizes the specifications for the supply current.

The maximum noise level should not exceed +/- 20 mV

To maintain interchangeability of all OEM-D1312(I) camera modules, the only listed module is the OEM-D1312(I)-160 module, because it has the highes consumption

Parameter	Symbol	MIN	TYP*	MAX
Supply Voltage	VDD_18	1.764 V	1.8 V	1.836 V
Supply Voltage	VDD_33	3.234 V	3.3 V	3.366 V
Supply Voltage	VDD_50	4.900 V	5.0 V	5.100 V
Supply Voltage	P_V	-	2.3 W	-

Table 5.1: Electrical characteristics of the OEM-D1312(I)-160 camera module (Indicated values are typical values at 25 °C)*

Parameter	Symbol	MIN	TYP*	MAX
Supply Current	IDD_18	-	0.288 A	0.349 A
Supply Current	IDD_33	-	0.370 A	0.473 A
Supply Current	DD_50	-	0.114 A	0.213 A

Table 5.2: Electrical characteristics of the OEM-D1312(I)-160 camera module (Indicated values are typical values at 25 °C*

It is recommended (but not necessary) to apply the 3.3 V supply voltage prior to the 1.8 V supply voltage. This will reduce inrush current on IDD_18 during startup.

5.1.2 Pinout PCB connector

The pinout of the OEM camera module PCB connector and the signal definitions are surmmarized in the following tables (see Table 5.3, Table 5.4, Table 5.5, and Table 5.6).

Pin	I/O	Name	Function
39	O	DATA19	Image data bit 19
37	O	DATA18	Image data bit 18
35	O	DATA17	Image data bit 17
33	O	DATA16	Image data bit 16
31	O	DATA15	Image data bit 15
29	O	DATA14	Image data bit 14
27	O	DATA13	Image data bit 13
25	O	DATA12	Image data bit 12
23	O	DATA11	Image data bit 11
21	O	DATA10	Image data bit 10
19	O	DATA9	Image data bit 9
17	O	DATA8	Image data bit 8
15	O	DATA7	Image data bit 7
13	O	DATA6	Image data bit 6
11	O	DATA5	Image data bit 5
9	O	DATA4	Image data bit 4
7	O	DATA3	Image data bit 3
5	O	DATA2	Image data bit 2
3	O	DATA1	Image data bit 1
1	O	DATA0	Image data bit 0

Table 5.3: Definition of the pinout of the OEM camera module PCB connector (odd row, pin 39 to 1)

Pin	I/O	Name	Function
79	PW	VDD_50	5.0 Volt power supply
77	PW	VDD_50	5.0 Volt power supply
75	PW	VDD_33	3.3 Volt power supply
73	PW	VDD_18	1.8 Volt power supply
71	O	DC_DC_CLK	DC/DC clock synchronisation pin for better noise performance. Fixed switching frequency of 1.666 MHz for this camera module. We do not recommend to use this pin. It is better to reduce power supply noise with an adequate filter.
69	O	STROBE	Special strobe output. Delay, polarity and pulsewidth can be configured via software.
67	I	TRIGGER	Special trigger input. Can be configured via software.
65	I	CC2	Reserved for future implementations, see Table 5.7 for additional information
63	I	CC4	Reserved for future implementations, see Table 5.7 for additional information
61	I	CC3	Reserved for future implementations, see Table 5.7 for additional information
59	I	CC1	Interface trigger input, used for standard external synchronization with user board, where the user board is the master and the camera module is the slave. Trigger will be accepted with positive edge of the signal.
57	O(I)	CL_SPARE	Reserved for future implementations
55	O	PIXEL_CLK	Pixel clock, data changes with rising edge
53	O	DATA_VALID	Data valid, indicates active data
51	O	LINE_VALID	Line valid, indicates active line
49	O	FRAME_VALID	Frame valid, indicates active frame
47	O	DATA23	Image data bit 23
45	O	DATA22	Image data bit 22
43	O	DATA21	Image data bit 21
41	O	DATA20	Image data bit 20

Table 5.4: Definition of the pinout of the OEM camera module PCB connector (odd row, pin 79 to 41)

Pin	I/O	Name	Function
40	I/O	RESERVED	Reserved for future implementations
38	PW	GND	Ground
36	O	LED_GREEN	Module status indicator. Indicates active image data transmission (inverted FRAME_VALID)
34	PW	GND	Ground
32	O	LED_RED	Module status indicator. Indicates active RS232 communication (LED_RED = RX and TX)
30	PW	GND	Ground
28	O	TCD	JTAG; Can be routed to a customer JTAG connector for future implementations; Do not connect this pin directly to your JTAG chain.
26	PW	GND	Ground
24	O	TMS	JTAG; Can be routed to a customer JTAG connector for future implementations; Do not connect this pin directly to your JTAG chain.
22	PW	GND	Ground
20	O	TDI	JTAG; Can be routed to a customer JTAG connector for future implementations; Do not connect this pin directly to your JTAG chain.
18	PW	GND	Ground
16	I	TDO	JTAG; Can be routed to a customer JTAG connector for future implementations; Do not connect this pin directly to your JTAG chain.
14	PW	GND	Ground
12	O	Misc_Analog	Reserved for future implementations; Miscellaneous analog voltage for customer specific purpose (0V..+5V). Not provided by all OEM camera module series.
10	PW	GND	Ground
8	O	MISC_DIGITAL	Module status indicator; can be used as user board reset, (active low)
6	PW	GND	Ground
4	O	Global Reset	Module status indicator; Indication of camera module state, (active low)
2	PW	GND	Ground

Table 5.5: Definition of the pinout of the OEM camera module PCB connector (even row, pin 40 to 2)

Pin	I/O	Name	Function
80	PW	VDD_50	5.0 Volt power supply
78	PW	VDD_33	3.3 Volt power supply
76	PW	VDD_33	3.3 Volt power supply
74	PW	VDD_18	1.8 Volt power supply
72	PW	GND	Ground
70	O	TX	TX RS232 interface (from camera), 3.3 V, see Section 5.3
68	I	RX	RX RS232 interface (to camera), 3.3 V, see Section 5.3
66	PW	GND	Ground
64	I/O	RESERVED	Reserved for future implementations
62	I/O	RESERVED	Reserved for future implementations
60	I/O	RESERVED	Reserved for future implementations
58	I/O	RESERVED	Reserved for future implementations
56	PW	GND	Ground
54	I/O	RESERVED	Reserved for future implementations
52	I/O	RESERVED	Reserved for future implementations
50	I/O	RESERVED	reserved for future implementations
48	I/O	RESERVED	Reserved for future implementations
46	PW	GND	Ground
44	I/O	RESERVED	Reserved for future implementations
42	PW	GND	Ground

Table 5.6: Definition of the pinout of the OEM camera module PCB connector (even row, pin 80 to 42)

Pins described as "reserved for future implementations" can (not a must) be connected with spare I/O signals on the customer's hardware side. All pins should be left floating (high impedance configuration) on customer's hardware side. For customer specific functionality these pins can be activated.

To enable the usage of both signal directions, please connect to I/O pins. If ever possible avoid dedicated single direction pins on FPGA's.

For minimum configuration (such as CameraLink like interfaces) we recommend the implementation of the following signals: CC1, CC2, CC3, CC4 and CL_SPARE.

5.2 Parallel Data Interface

The interface of the OEM camera modules is a parallel data interface, which follows the AIA standard. On the module connector the signals are available in a parallel format. The AIA standard contains signals for transferring the image data, control information and the serial communication

Data signals: Data signals contain the image data. In addition, handshaking signals such as FVAL, LVAL and DVAL are transmitted (see Table 5.7).

Camera control information: Camera control signals (CC-signals) can be defined by the camera manufacturer to provide certain signals to the camera. There are 4 CC-signals available and all are unidirectional with data flowing from the frame grabber to the camera. For example, the external trigger is provided by a CC-signal (see Table 5.7 for the CC assignment).

CC1	TRIGGER	Interface trigger input, used for standard external synchronization with user board, where the user board is the master and the camera module is the slave. Trigger will be accepted with positive edge of the signal.
CC2	CTRL0	Control0. This signal is reserved for future purposes and is not used.
CC3	CTRL1	Control1. This signal is reserved for future purposes and is not used.
CC4	CTRL2	Control2. This signal is reserved for future purposes and is not used.

Table 5.7: Summary of the Camera Module Control (CC) signals as used by Photonfocus

Pixel clock: The pixel clock is generated on the camera module and is provided to the following electronics for synchronisation.

Serial communication: The camera module can be controlled by the user via a RS232 compatible asynchronous serial interface. Refer to Section Section 5.3 for more information.

The user's vision system needs to be configured with the proper tap and resolution settings, otherwise the image will be distorted or not displayed with the correct aspect ratio. Refer to Section 3.4 for the parameters needed for interfacing.

5.3 Configuration of the OEM Communication Interface

The OEM camera modules can be controlled by the user via a RS232 compatible asynchronous serial interface with LVCMOS levels. The interface is accessible via the board connectors.

The baud rate of the camera module communication can be configured via software. At the moment the baud rates of 9600 baud or 57600 baud are supported.

6 The PFRemote Control Tool

6.1 Overview

PFRemote is a graphical configuration tool for Photonfocus cameras. The latest release can be downloaded from the support area of www.photonfocus.com .
All Photonfocus cameras can be either configured by PFRemote, or they can be programmed with custom software using the PFLib SDK ([PFLIB]).

6.2 PFRemote and PFLib

As shown in Fig. 6.1, the camera parameters can be controlled by PFRemote and PFLib respectively. To grab an image use the software or the SDK that was delivered with your frame grabber.

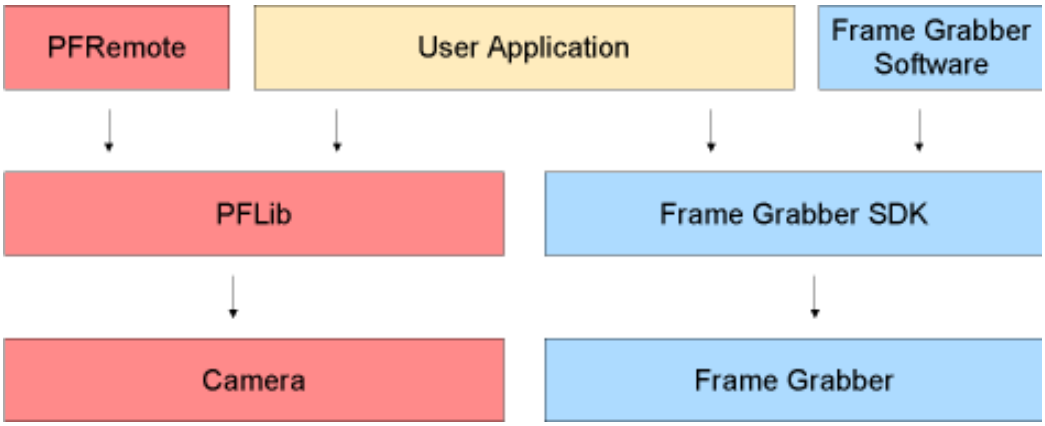


Figure 6.1: PFRemote and PFLib in context with the CameraLink frame grabber software

6.3 Operating System

The PFRemote GUI is available for Windows OS only. For Linux or QNX operating systems, we provide the necessary libraries to control the camera on request, but there is no graphical user interface available.

If you require support for Linux or QNX operating systems, you may contact us for details of support conditions.

6.4 Installation Notes

Before installing the required software with the PFInstaller, make sure that your frame grabber software is installed correctly.
Several DLLs are necessary in order to be able to communicate with the cameras:

- PFCAM.DLL: The main DLL file that handles camera detection, switching to specific camera DLL and provides the interface for the SDK.
- 'CAMERANAME'.DLL: Specific camera DLL, e.g. mv_d1024e_3d01_160.dll.
- COMDLL.DLL: Communication DLL. This COMDLL is not necessarily CameraLink® specific, but may depend on a CameraLink® API compatible DLL, which should also be provided by your frame grabber manufacturer.
- CLALLSERIAL.DLL: Interface to CameraLink® frame grabber which supports the clallserial.dll.
- CLSER_USB.DLL: Interface to USB port.

More information about these DLLs is available in the SDK documentation [SW002].

6.5 Graphical User Interface (GUI)

PFRemote consists of a main window (Fig. 6.2) and a configuration dialog. In the main window, the camera port can be opened or closed, and log messages are displayed at the bottom. The configuration dialog appears as a sub window as soon as a camera port was opened successfully. In the sub window of PFRemote the user can configure the camera properties. The following sections describe the general structure of PFRemote.

6.5.1 Port Browser

On start, PFRemote displays a list of available communication ports in the main window.

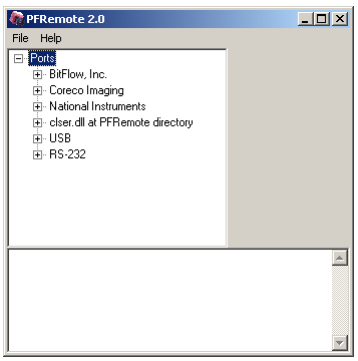


Figure 6.2: PFRemote main window with PortBrowser and log messages

To open a camera on a specific port double click on the port name (e.g. USB). Alternatively right click on the port name and choose **Open & Configure...**. The port is then queried for a compatible Photonfocus camera.
In the PFRemote main window, there are two menus with the following entries available:

File Menu

Clear Log: Clears the log file buffer

Quit: Exit the program

Help Menu

About: Copyright notice and version information

Help F1: Invoke the online help (PFRemote documentation)

6.5.2 Ports, Device Initialization

After starting **PFRemote**, the main window as shown in Fig. 6.2 will appear. In the PortBrowser in the upper left corner you will see a list of supported ports.

Depending on the configuration, your port names may differ, and not every port may be functional.

If your frame grabber supports clallserial.dll version 1.1 (CameraLink® compliant standard Oct 2001), the name of the manufacturer is shown in the PortBrowser.

If your frame grabber supports clallserial.dll version 1.0 (CameraLink® compliant standard Oct 2000), the PortBrowser shows either the name of the dll or the manufacturer name or displays "Unknown".

If your frame grabber does not support clallserial.dll, copy the clserXXXX.dll of your frame grabber in the PFRemote directory and rename it to clser.dll. The PortBrowser will then indicate this DLL as "clser.dll at PFRemote directory".

After connecting the camera, the device can be opened with a double click on the port name or by right-clicking on the port name and choosing **Open & Configure**. If the initialisation of the camera was successful, the configuration dialog will open. The device is closed when PFRemote is closed. Alternatively, e.g. when connecting another camera or evaluation kit, the device can also be closed explicitely by right clicking on the port name and choosing **Close**. Make sure that the configuration dialog is closed prior to closing the port.

Errors, warnings or other important activities are logged in a log window at the bottom of the main window.

If the device does not open, check the following:

- Is the power LED of the camera active? Do you get an image in the display software of your frame grabber?
- Verify all cable connections and the power supply.
- Check the communication LED of the camera: do you see some activity when you try to access the camera?

6.5.3 Main Buttons

The buttons on the right side of the configuration dialog store and reset the camera configuration.

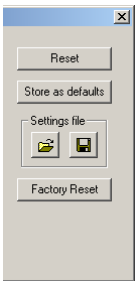


Figure 6.3: Main buttons

Reset: Reset the camera and load the default configuration.

Store as defaults: Store the current configuration in the camera flash memory as the default configuration. After a reset, the camera will load this configuration by default.

Settings file - File Load: Load a stored configuration from a file.

Settings file - File Save: Save current configuration to a file.

Factory Reset: Reset camera and reset the configuration to the factory defaults.

6.6 Device Properties

Cameras or sensor devices are generally addressed as ‘device’ in this software. These devices have properties that are accessed by a property name. These property names are translated into register accesses on the driver DLL. The property names are reflected in the GUI as far as practicable. A property name normally has a special mark up throughout this document, for example: `ExposureTime`. Some properties are grouped into a structure whose member is accessed via dot notation, e.g. `Window.X` (for the start X value of a region of interest). When changing a property, the property name can always be seen in the log window of the main program window.

7

Mechanical and Optical Considerations

7.1 Mechanical Interface

During storage and transport, the camera modules should be protected against vibration, shock, moisture and dust. The original packaging protects the camera modules adequately from vibration and shock during storage and transport. Please either retain this packaging for possible later use or dispose of the packaging according to local regulations.

7.1.1 Camera Modules Dimensions and Mounting

The mechanical dimensions of the OEM-D1312(I) sensor modules are given in Fig. 7.1 and the mechanical dimensions of the ADC module are given in Fig. 7.2.

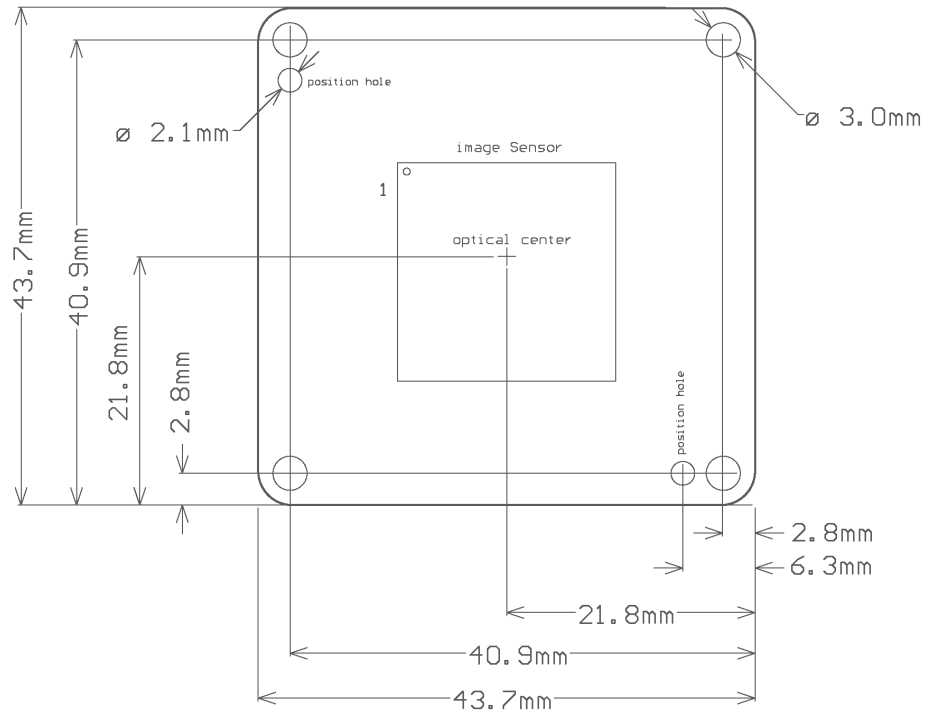


Figure 7.1: Mechanical dimensions of the OEM-D1312(I) sensor module

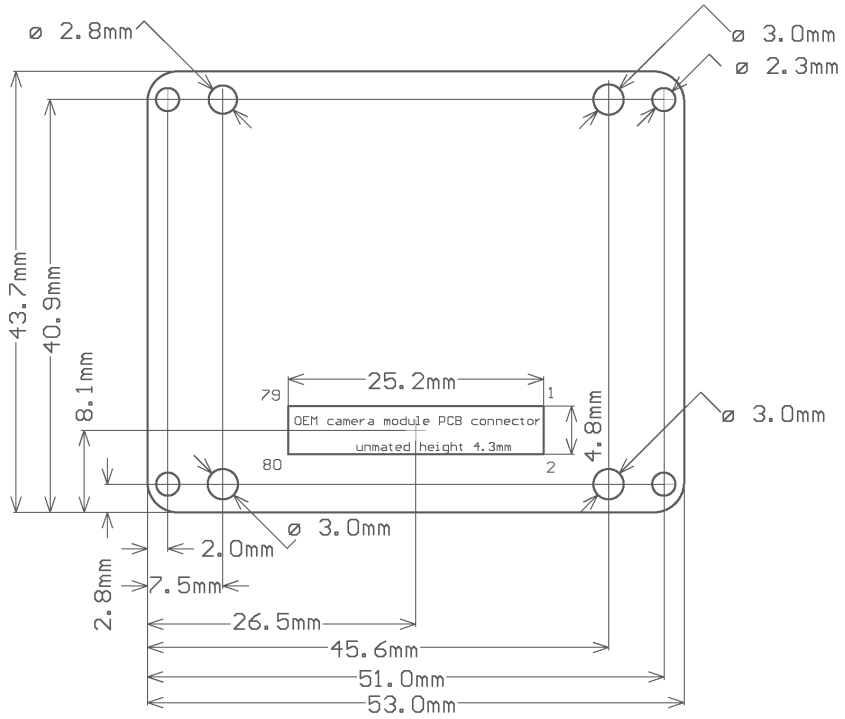


Figure 7.2: Mechanical dimensions of the OEM-D1312(I) ADC module

Fig. 7.3 provides an overview of the two-board OEM camera solution. The sensor module is displayed with the view from the sensor side and the ADC module is shown from the interface side. The pin numbers of the PCB board-to-board connectors are indicated for clarity of pin assignment. It also gives the stacking height of the stacked sensor and ADC board. The hatched regions in Fig. 7.3 indicate the copper coated areas for thermal cooling of the sensor board.

Customer housing should be designed to contact with the copper area for maximum heat sink to reduce noise.

Several temperature monitors are integrated on the camera modules to supervise system reliability.

During development phase, the temperature monitors can be used to check whether the customers housing sufficiantly supports the heat sink.

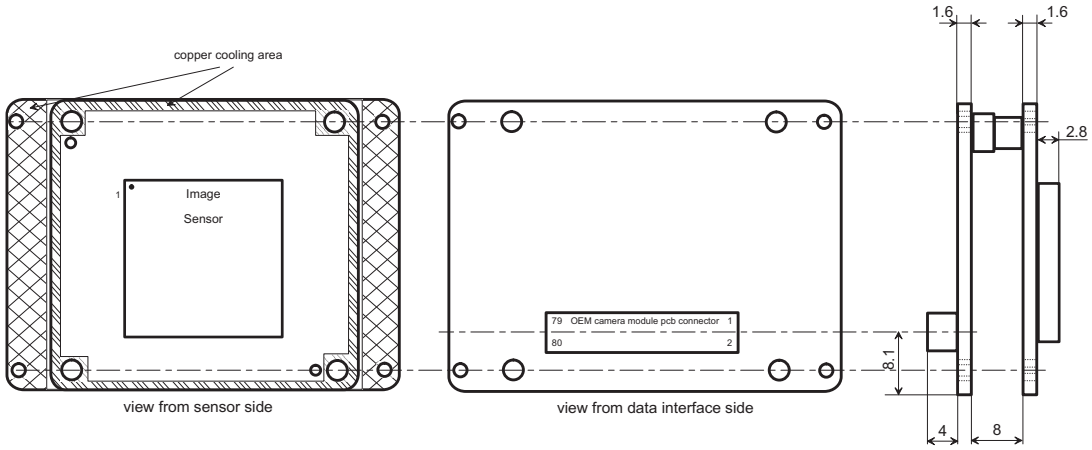


Figure 7.3: Mechanical dimensions of the two-board OEM solution with view from the sensor side (left), from the data interface side (middle) and with view from the side (right)

The optical centre of the pixel matrix is located centrally in the sensor package (see Fig. 7.4). The sensor die is encapsulated using a black epoxy passivation material. The optically active area of the A1312 sensor is free of this material. the absence of a glass lid minimizes the number of elements in the optical path to the sensor.

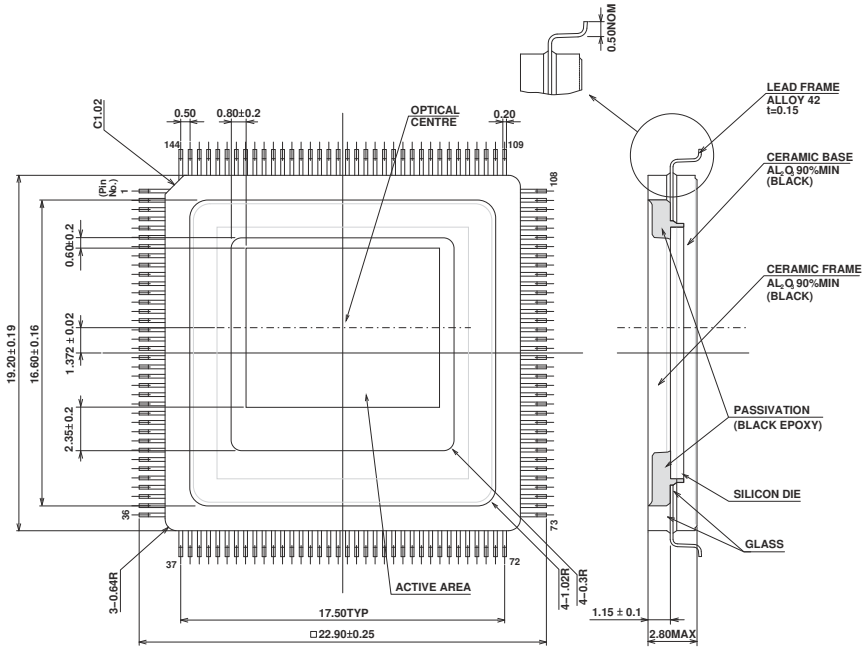


Figure 7.4: Outline dimensions of the A1312(I) sensor in the OEM-D1312(I) module

Future sensors (e.g. colour sensors) may be equipped with special filter or glass lids and will be differing from the dimensions shown in Fig. 7.4. Customer housings should include additional space in case that future modules shall be implemented in existing OEM solutions.

The upper surface of the sensor is resistant to common solvents and cleaning solutions. Nevertheless, care must be taken when handling or cleaning the sensor, particularly since scratching may result. For further details on sensor cleaning, please refer to Section 7.2.1.

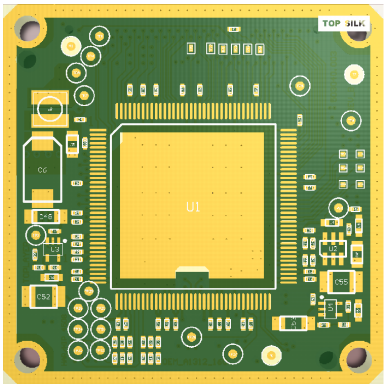


Figure 7.5: Overview of the OEM-D1312(I) sensor module (top view)

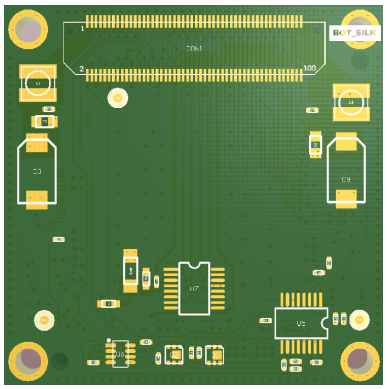


Figure 7.6: Overview of the OEM-D1312(I) sensor module (bottom view)

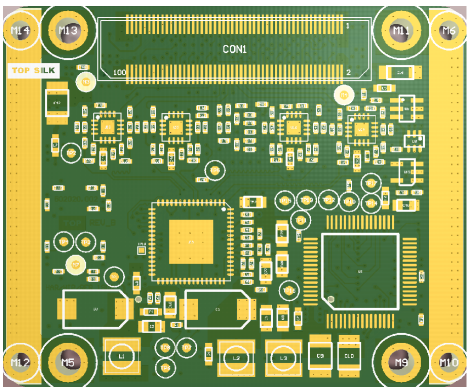


Figure 7.7: Overview of the ADC board of the OEM-D1312(I) module (top view)

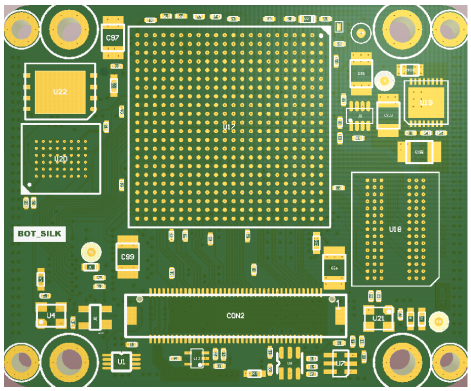


Figure 7.8: Overview of the ADC board of the OEM-D1312(I) module (bottom view)

7.1.2 Possible Customer Module Solution and Dimensions

Fig. 7.9 presents a proposal for a possible solution for the customer with the pin numbers indicated for clarity of pin assignment. In Fig. 7.9 the overall stacking height is given for the complete customer module solution.

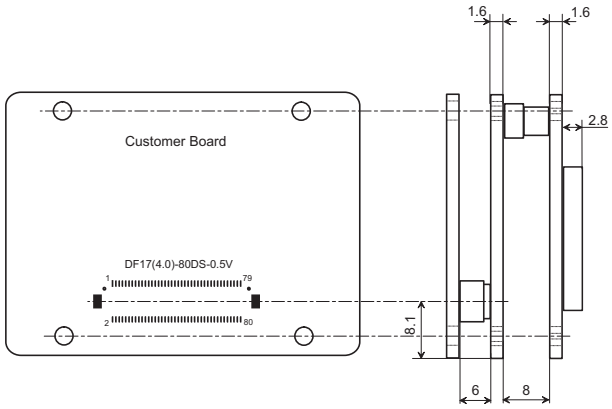


Figure 7.9: Possible solution

7.1.3 Module Connector

The PCB board-to-board connectors (DF17 series, two-piece connector, stacking height 5-8 mm) are available from Hirose (www.hirose-connectors.com). Details of the order numbers are listed in Table 7.1.

Connector type	Part Number	virtual height	location
Header	DF17(2.0)-80DP-0.5V	2 mm	ADC board (Photonfocus side)
Receptable	DF17(4.0)-80DS-0.5V	4 mm	ADC board (customer side)
Receptable	DF17(3.0)-80DS-0.5V	3 mm	ADC board (customer side)

Table 7.1: Ordering details of the PCB board-to-board connectors (HRS connectors)

All parts on the PCB boards implemented by Photonfocus are $\leq$ 3mm.

Please check for the overall mounting height of the PCB board-to-board connector (see Fig. 7.10). The choice of a 5 mm receptable may result in part collision.

<table>
<tr><td colspan="2" rowspan="2">Receptable
Customer side

Header
Photonfocus side</td><td colspan="2">DF17(?.?)-80DS-0.5V</td></tr>
<tr><td>3 mm
 </td><td>4 mm
 </td></tr>
<tr><td>DF17(2.0)-80DP-0.5V</td><td>2 mm
 </td><td>mating height
5 mm
(not recommended)</td><td>mating height
6 mm</td></tr>
</table>

Figure 7.10: Mating height of the header and receptable of the PCB board-to-board connectors (Hirose connectors)

7.2 Optical Interface

7.2.1 Cleaning the Sensor

The sensor is part of the optical path and should be handled like other optical components: **with extreme care**.
Dust can obscure pixels, producing dark patches in the images captured. Dust is most visible when the illumination is collimated. Dark patches caused by dust or dirt shift position as the angle of illumination changes. Dust is normally not visible when the sensor is positioned at the exit port of an integrating sphere, where the illumination is diffuse.

1. The camera modules should only be cleaned in ESD-safe areas by ESD-trained personnel using wrist straps. Ideally, the sensor should be cleaned in a clean environment. Otherwise, in dusty environments, the sensor will immediately become dirty again after cleaning.
2. Use a high quality, low pressure air duster (e.g. Electrolube EAD400D, pure compressed inert gas, www.electrolube.com) to blow off loose particles. This step alone is usually sufficient to clean the sensor of the most common contaminants.

   Workshop air supply is not appropriate and may cause permanent damage to the sensor.

3. If further cleaning is required, use a suitable lens wiper or Q-Tip moistened with an appropriate cleaning fluid to wipe the sensor surface as described below. Examples of suitable lens cleaning materials are given in Table 7.2. Cleaning materials must be ESD-safe, lint-free and free from particles that may scratch the sensor surface.

   Do not use ordinary cotton buds. These do not fulfil the above requirements and permanent damage to the sensor may result.

4. Wipe the sensor carefully and slowly. First remove coarse particles and dirt from the sensor using Q-Tips soaked in 2-propanol, applying as little pressure as possible. Using a method similar to that used for cleaning optical surfaces, clean the sensor by starting at any corner of the sensor and working towards the opposite corner. Finally, repeat the procedure with methanol to remove streaks. It is imperative that no pressure be applied to the surface of the sensor or to the black globe-top material (if present) surrounding the optically active surface during the cleaning process.

Product		Supplier	Remark
EAD400D	Airduster	Electrolube, UK	www.electrolube.com
Anticon Gold 9"x 9"	Wiper	Milliken, USA	ESD safe and suitable for class 100 environments. www.milliken.com
TX4025	Wiper	Texwipe	www.texwipe.com
Transplex	Swab	Texwipe	
Small Q-Tips SWABS BB-003	Q-tips	Hans J. Michael GmbH, Germany	www.hjm-reinraum.de
Large Q-Tips SWABS CA-003	Q-tips	Hans J. Michael GmbH, Germany	
Point Slim HUBY-340	Q-tips	Hans J. Michael GmbH, Germany	
Methanol	Fluid	Johnson Matthey GmbH, Germany	Semiconductor Grade 99.9% min (Assay), Merck 12,6024, UN1230, slightly flammable and poisonous. www.alfa-chemcat.com
2-Propanol (Iso-Propanol)	Fluid	Johnson Matthey GmbH, Germany	Semiconductor Grade 99.5% min (Assay) Merck 12,5227, UN1219, slightly flammable. www.alfa-chemcat.com

Table 7.2: Recommended materials for sensor cleaning

For cleaning the sensor, Photonfocus recommends the products available from the suppliers as listed in Table 7.2.

Cleaning tools (except chemicals) can be purchased directly from Photonfocus (www.photonfocus.com).

8 Warranty

The manufacturer alone reserves the right to recognize warranty claims.

8.1 Warranty Terms

The manufacturer warrants to distributor and end customer that for a period of two years from the date of the shipment from manufacturer or distributor to end customer (the "Warranty Period") that:

- the product will substantially conform to the specifications set forth in the applicable documentation published by the manufacturer and accompanying said product, and
- the product shall be free from defects in materials and workmanship under normal use.

The distributor shall not make or pass on to any party any warranty or representation on behalf of the manufacturer other than or inconsistent with the above limited warranty set.

8.2 Warranty Claim

The above warranty does not apply to any product that has been modified or altered by any party other than manufacturer, or for any defects caused by any use of the product in a manner for which it was not designed, or by the negligence of any party other than manufacturer.

9

References

All referenced documents can be downloaded from our website at www.photonfocus.com.

CL CameraLink® Specification, January 2004

SW002 PFLib Documentation, Photonfocus, August 2005

AN006 Application Note "Quantum Efficiency", Photonfocus, February 2004

AN007 Application Note "Camera Acquisition Modes", Photonfocus, March 2004

AN008 Application Note "Photometry versus Radiometry", Photonfocus, December 2004

AN010 Application Note "Camera Clock Concepts", Photonfocus, July 2004

AN026 Application Note "LFSR Test Images", Photonfocus, September 2005

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Revision History

Revision	Date	Changes
2.1	October 2010	Section Functionality / Test Images: added note that a flat histogram is only obtained at a resolution of 1024 x 1024 pixels.
		Section Mechanical and Optical Considerations / Optical Interface / Cleaning the Sensor: updated link to supplier web page.
2.0	August 2009	Description of new features added: MROI, Region-LUT, Crosshairs
		Description of new features added: soft trigger, 3x3 convolver
		Sections in Chapter Functionality and Hardware Interface reordered.
		Added example images to some sections.
		Added models OEM-D1312(I)-40, and OEM-D1312(I)-80
		Added model OEM-D1312-I-160
1.0	December 2008	First release